SPSE

Photographic SCIENCE AND ENGINEERING

Contrast Rendition as a Design Tool • *Roderic M. Scott* 201

A Method of Contrast Control in Continuous-Tone Xerography
J. T. Bickmore, R. E. Hayford, and H. E. Clark 210

Photothermographic Sensitization of Mercurous Oxalate by Mercurous and Silver Iodides
P. B. Gilman, Jr., P. A. Vaughan, and P. A. van der Meulen 215

An Edge Effect in Color Films Caused by Distortion of the Developed Image when a Hardening Bleach Is Used • *H. J. Bello, Jr., and D. M. Zwick* 221

Comparison of the Kinetics of Development of Silver Chloride and Silver Bromide Emulsions • *T. H. James* 225

Adsorption and Structure of Sensitizing Dyes • *E. Klein and F. Moll* 232

Book and Journal Reviews 235

Notes from the Editor 241

New Products and Developments • *Frank Smith* 242

1959 National Conference Notice 247

Advance Program, 1959 NATIONAL CONFERENCE 248

October 26–30, Edgewater Beach Hotel, Chicago

Volume 3 · Number 5

SEPTEMBER-OCTOBER · 1959

Editorial Policy

Photographic Science and Engineering is dedicated to the advancement of the knowledge and application of photography and other directly related sciences. Its pages are open to all who wish to report on new studies dealing with the theory of photosensitive systems, the design of photographic instruments and apparatus useful in the treatment of photographic materials, photographic optics and illuminants, the use of photography for scientific or engineering measurement or recording, and photographic instrumentation and data recording. Only original papers should be submitted except on special invitation.

Manuscripts should be typed double-spaced on white bond paper with $1^1/_4$-inch margins all around. Literature references should be exact, and should include titles of journals, names of authors, numbers of volumes and pages, and year of publication. Book references should include title of volume, names of authors, publisher, number of edition, year of publication, and chapter and pages cited.

Graphs, charts, and other line illustrations should conform to good usage such as given in the American Standards Association Document Y-15, "A Guide for Preparing Technical Illustrations for Publication and Projection." Continuous-tone photographs should be made on 8 by 10-inch glossy paper and should show pertinent image detail sufficiently clearly to permit reduction to fit a 3-inch column in this journal. All illustrations should be numbered in soft blue pencil on the back to correspond with captions typed on a separate page. Tables should also be submitted on separate pages appropriately identified. An abstract should accompany each manuscript.

Papers intended for publication (two copies) and books for review should be submitted to the editor, T. H. James, Research Laboratories, Eastman Kodak Co., Rochester 4, N.Y. Correspondence regarding proofs and reprints should be directed to Mrs. Jennie H. Allen, 94 Hastings Ave., Croton-on-Hudson, N.Y. All papers submitted for publication will be reviewed by members of the Editorial Review Board and if not accepted will be returned to the author. Published papers become the property of the Society and are protected by appropriate copyrights. Authors receive five copies of issues in which their contributions appear. Authors may order reprints of their papers at the time they return the galley proofs. The Society does not assume responsibility for material in transit, nor guarantee publication of unsolicited material.

Photographic
SCIENCE AND ENGINEERING

official publication of the
Society of Photographic Scientists and Engineers

September-October 1959

Volume 3, Number 5

EDITORIAL STAFF

T. H. James, ***Editor***
Jennie H. Allen, ***Managing Editor***
S. C. Goddard, ***Feature Editor***
Frank Smith, ***Feature Editor***
Norman A. Exley, ***Assistant Editor***

EDITORIAL REVIEW BOARD

R. S. Barrows
R. Clark Jones
Peter Krause
K. G. Leistner
J. A. Maurer
F. W. H. Mueller
H. F. Nitka
Thomas D. Smith
William West

Photographic Science and Engineering is published six times a year by the Society of Photographic Scientists and Engineers.

• Address remittances, orders for subscriptions and for single copies, claims for missing numbers, and notices of change of address to the Society at Box 1609, Main Post Office, Washington, D. C. Subscription to non-members of the Society, $8.00 per year, to members $4.00; single copies, $2.00 each.

• The publication office is at 20th and Northampton Streets, Easton, Pa. Second-class mail privileges authorized at Easton, Pa. This publication is authorized to be mailed at the special rates of postage prescribed by Section 132.122.

• The Society is not responsible for the accuracy of statements made by authors and does not necessarily subscribe to their views.

© Copyright 1959 by the Society of Photographic Scientists and Engineers, Inc. Permission to reprint any part of the contents, except in reviews and abstracts, must be obtained in writing from the Editorial Vice President.

PHOTOGRAPHIC SCIENCE AND ENGINEERING
Volume 3, Number 5, September-October 1959

Contrast Rendition as a Design Tool

RODERIC M. SCOTT, *The Perkin-Elmer Corporation, Norwalk, Conn.*

Recent work on the part of many investigators has made available the basic data required for the analysis of optical systems from the point of view of information transfer characteristics. Methods, both theoretical and experimental, for the determination of the transfer functions of optical lenses themselves are now available. In addition, both photographic materials and photoelectric devices have been and are being extensively studied from the same point of view.

In this paper, the additional contributions to the transfer function of image motion, both direct and vibration, are added to the available tools of the method. The random deflections produced by atmospheric seeing are treated in a manner to make them consistent with the other transfer functions. Several examples of the method of combining optics and detector and image motion are presented and the predicted performance of the various systems resulting from these combinations is discussed.

The designer of a photographic system is often faced with the problem of finding a compromise between coverage, resolution, size, weight, and cost. Although these factors are controlling influences in the design of reconnaissance systems, they play important roles in any camera system. While it would be most desirable to involve all the variables of such a system in a master relation which could be studied and optimized from any desired point of view, such a relation, if it could be developed, would in all probability be so cumbersome and complex that its usefulness would be quite limited. The alternate approach, that of assuming a system embodying as many of the desirable features as possible and computing the values of the remaining variables, has the advantage of keeping the designer close to the physical problems.

A reliable method of predicting actual usefulness under operating conditions is a prerequisite of this pragmatic analysis. All of the factors affecting the ability of a system to provide the mechanism of intelligence transfer from the original scene to the ultimate user must be described in such fashion that they may be manipulated by the designer. It is not the purpose of this paper to examine in any exhaustive treatment all of these factors. Rather, it shall be attempted here to present certain relations and methods which help the designer to understand the effects of the many compromises forced upon him, on the ability of a system to resolve detail in the scene as that detail varies in contrast.

As an example, a designer may ask himself whether a reconnaissance system confined to a certain volume is better if made up of a fast lens of short focal length using slow film, or a slow lens of long focal length using fast film. From the standpoint of resolution alone, the current art leads to the second choice but, since the volume is fixed, the long focal-length lens, because it requires more film to cover a given area, may be severely limited in its total coverage. Thus, if a compromise between resolution and coverage must be made, this can only be done wisely if the expected resolution of the extreme cases and many between can be accurately predicted.

A further use for the method to be discussed is the setting of tolerances on such factors as vibration, stabilization, and image motion compensation so that a desired resolution level may be obtained in actual use.

Presented at the Annual Conference, Rochester, N.Y., 10 October 1958. Received 12 September 1958; revised 17 June 1959.

Basic Methods

A complex system—optical, electronic, or a combination—may be most easily investigated if the contributions of each component to the over-all performance can be expressed in such a way that these individual contributions may be added or multiplied (added logarithmically) to give the system performance. Schade[1] has shown how this can be done for the combination of optical and electronic components of television systems. Other authors[2–4] have examined methods of evaluating the contribution of the lens and the emulsion of a photographic system.

An optical system, including the detector, has the characteristic that the contrast in the final image is different from that in the object in a manner dependent on the size of the detail in the image. As the detail becomes smaller it is reproduced at lower and lower contrast and at some detail size the system fails to provide sufficient contrast in the image for detection. The description of this ability, or lack thereof, to transfer contrast from the scene to the image is here called the transfer function. R. Clark Jones[5] has listed many other names for the same characteristic. Since the transfer function is a function of detail size, it is convenient to express it as dependent on the wavelength or space frequency of a sinusoidally vary-

ing intensity in the image. Consider a scene in which the intensity varies according to the following relation:

$$I_o = I_{Ao} + I_{Vo} \sin \frac{2\pi x}{x_o} \tag{1}$$

This is a series of lines spaced x_o apart. The maximum intensity is $I_{Ao} + I_{Vo}$ and the minimum intensity between the lines is $I_{Ao} - I_{Vo}$. While this might seem an artificial sort of scene to consider, its usefulness comes from the fact that any variation of intensity along a single direction in the scene may be represented as the sum of a large number of such sinusoids with decreasing x_o each with a different amplitude and phase angle.

In the image produced by the system

$$I_i = I_{Ai} + I_{Vi} \sin \frac{2\pi x'}{x_o'} \tag{2}$$

Here I_{Ai} is the average intensity of the image and is related to I_{Ao}, the average intensity of the object, by the transmission of the system. The varying part of the image has an amplitude I_{Vi} for the wavelength x_o'. The lengths x_o' and x' are related to x_o and x by the magnification of the system. In a perfect system $I_{Ai} = I_{Ao}$ and $I_{Vi} = I_{Vo}$, but in any real system $I_{Ai} = \tau I_{Ao}$ and $I_{Vi} = T(x_o') I_{Vo}$. Here τ is the transmission of the system and $T(x_o')$ is the transfer function.

Observe that if $I_{Vo} = I_{Ao}$ the lines vary from zero intensity to $2I_{Ao}$ and the modulation is 100% or unity. Then modulation of intensity in the image of wavelength x_o' is $I_{Vi}/I_{Ai} = I_{Vi}/I_{Vo}$ or exactly $T(x_o')$, the transfer function. Thus, the transfer function may be determined by measuring the intensity variations in the image for objects of unity modulation and different wavelengths.

Modulation differs from that property of scenes or images referred to as the contrast but is related to it by

$$M = \frac{C - 1}{C + 1}, \quad C = \frac{1 + M}{1 - M} \tag{3}$$

when by contrast is meant the ratio of intensities. In terms of the logarithmic contrast

$$M = \frac{10^C - 1}{10^C + 1}, \quad C = \log \frac{1 + M}{1 - M} \tag{4}$$

Now consider a system of more than one element. The lens sees the scene and produces an image whose characteristics are described by Relation (2) in which

$$I_{Vi} = T_L(x_o') I_{Vo} \tag{5}$$

Here $T_L(x_o')$ is the transfer function for the lens alone. This function is just as much a physical characteristic of the lens as the focal length or clear aperture. It is a bit harder to measure than these other properties and, in addition, it varies from point to point in the focal plane and may even be dependent on the directions chosen for the x direction at a particular point. Such a dependence on direction is the case where the image of a point source produced by the lens is not symmetrical.

The photographic material sees a scene which is the image produced by the lens and, in turn, produces an image as seen by the printing paper or by the eye in transmitted light. It also has a transfer function relating the modulation of the scene as presented to the film and the image the film presents to the eye. As before, the variable part of the image is

$$I_{ip} = T_p(x_o') I_{op} \tag{6}$$

where the subscripts are used to indicate object and image and also the association with the photographic process. Combining Relations (5) and (6)

$$I_{ip} = T_p(x_o') T_L(x_o') I_o \tag{7}$$

Had there been any other components in the system which affect the modulation in the image, these too could have been included in the relation. Thus, the transfer function for a system is the product of the transfer functions for each component or effect.

In a reconnaissance system the mechanisms to be considered are the atmosphere, the optics, the effects of motion, both linear and vibratory, and the film. In each case, one must start with that which can be measured or assumed about the effect, and then convert this information into a transfer function. Since the starting information is generally of the nature of the effect on a point or line source, a mechanism for converting such information to the transfer function is required. Jones has provided the necessary relations.[5]

The Atmosphere

The atmospheric effects on system performance can be divided into two types. The first of these, scattering, affects the modulation because some light from the sun is scattered directly into the system and some image-forming light from the scene is scattered out of the system. These effects are the result of large-angle scattering by haze and thus are not functions of x_o, the wavelength of the detail in the scene. The effect then is a general reduction of contrast or modulation independent of detail size. This is still an important factor, however, for in effect, it reduces the available modulation in the scene as seen by the system. For photography through long paths, 5 or 6 miles or more, in the atmosphere, whether vertical or horizontal, the transfer function for scattering even under the best conditions does not become larger than about 0.8.[6]

An investigation of more typical atmospheric conditions indicates that a good average value for the transfer function might be 0.225 or 0.25. These numbers are not as precise as the significant places would indicate, but are consistent with a logarithmic contrast of 0.2.[7]

The second atmospheric effect is small-angle scattering arising from density variations of the air. While

there are such density variations due to turbulence and temperature fluctuations throughout the atmosphere, there are two regions in which these effects are particularly noticeable. The most important, unless particular care is taken, is the region very close to the camera. For airborne systems the turbulence in the boundary layer over the camera itself or the window through which it looks will be the principle atmospheric effect. For stationary systems such as telescopes, the air in the ground layer, around the instrument, or even in the instrument, may well be the predominant contribution to the seeing. The effect of the boundary layer has been investigated in theory[8] and by wind tunnel tests.[9] The results indicate that the scattering is a function of both altitude and speed. It is best expressed as a random angular displacement of the rays making up the image. The turbulent cells are both small and fast moving so that the effect does not depend on exposure time or aperture.

The other region of interest is the tropopause. In this layer are formed turbulent cells of the order of 20 cm in size, moving with reasonably slow velocities.[10,11] The scattering produced here is random, with a root mean square value measured at night of about 1.5 sec of arc. Only for systems of the highest acuity is this effect of importance. It is the one effect, however, which sets a limit to the increase of resolution with focal length. This limit arises because longer focal lengths require larger apertures, if the exposure is to be kept short. When the aperture is larger than the cell size the resolution is limited by the effect of the atmosphere even though the exposure is very short.

Since these atmospheric effects may be considered as random angular displacements, a transfer function for such processes is desired. If the deflection is a random function of position and time, the probability of a deflection of size r is given by

$$P(r) = \frac{1}{2\pi a^2} e^{-r^2/2a^2} \tag{8}$$

provided every direction of deflection is equally probable. Here a is the root mean square deviation. It follows then that a point source would be imaged by a perfect system through such a scattering medium as an image with the shape

$$C(r) = \frac{1}{2\pi a^2} e^{-r^2/2a^2} \tag{9}$$

In fact, a is usually determined by observing the shape of such images. If, however, a bright line is used as a source, the shape of the image will be

$$A(x) = \frac{1}{a\sqrt{2\pi}} e^{-x^2/2a^2} \tag{10}$$

The root mean square value a is the same as before in Relation (9).

The transfer function $T(k)$ may now be found from the relations given by Jones[5]

$$T(k) = 2\pi \int_{-\infty}^{+\infty} C(r)\, J_o(2\pi kr)\, r dr \tag{11}$$

or

$$T(k) = \int_{-\infty}^{+\infty} A(x) \cos(2\pi kx)\, dx \tag{12}$$

The substitution $k = 1/x_o$ has been made to bring the notation into line with that of Jones. Either of these equations yield

$$T(k) = e^{-2\pi^2 a^2 k^2}, \tag{13}$$

the desired transfer function. The image profile for such a random deflection is shown as the lowest curve in Fig. 1. The transfer function itself is plotted on logarithmic scales in Fig. 2. This transfer function is applicable whether the image moves as a whole in a random fashion or whether the individual rays mak-

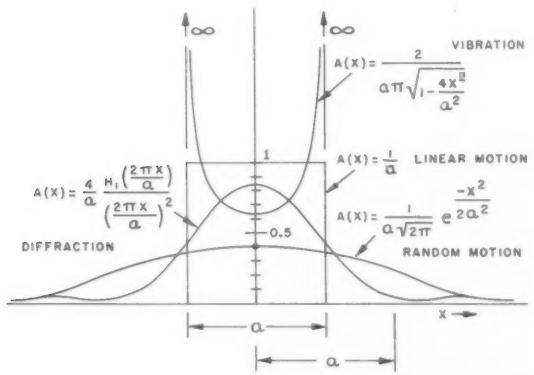


Fig. 1. Line-spread functions — the distribution of intensity in an image of a line under various conditions of motion.

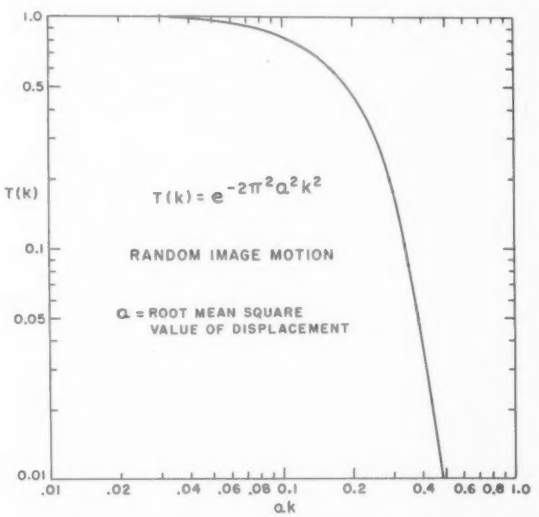


Fig. 2. The transfer function for random image motion.

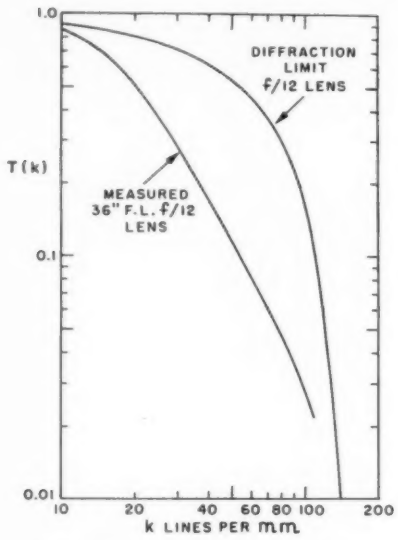


Fig. 3. The transfer function for an f/12 lens.

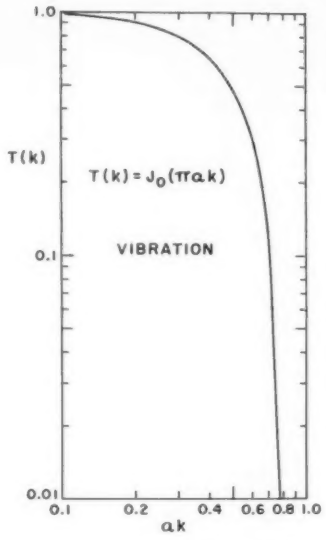


Fig. 4. The transfer function for vibration.

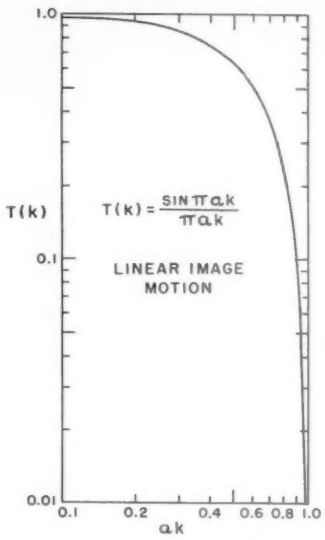


Fig. 5. The transfer function for linear image motion.

ing up the image suffer random deflection. The only requirement is that the exposure and aperture integrate enough deflections to produce a symmetrical image of the form of Relation (9) or (10).

The Lens

The transfer function for the lens of our system is, as has been indicated before, rather difficult to obtain. If a lens of the type being considered is available, the transfer function can be measured directly. Several machines for this purpose have been developed and are now in use.[12–15] However, for proposed lenses the prediction of the performance becomes largely a matter of estimating how close to the diffraction limit a lens will perform. Because of the finite wavelength of light, the best resolution that any lens can produce is determined by the aperture of the lens.

A circular aperture has a diffraction pattern such that the image of a point source has an intensity distribution given by[16]

$$C(r) = 4\,\frac{J_1^2(\pi r/a)}{(\pi r/a)^2} \tag{14}$$

In this relation, $a = \lambda f/2R = \lambda N$ where λ is the wavelength of the light, R is the radius of the aperture, f is the focal length of the lens, and N is the f number, $N = f/2R$. $J_1(\pi r/a)$ is the first order Bessel function.

By use of the relation V from Jones,[5] the shape of the image of a bright line is found to be

$$A(x) = 2\int_x^\infty C(r)\,(r^2 - x^2)^{-1/2}\,r\,dr \tag{15}$$

$$= \frac{4}{a}\cdot\frac{H_1\left(\frac{2\pi x}{a}\right)}{\left(\frac{2\pi x}{a}\right)^2} \tag{16}$$

Here $H_1(2\pi x/a)$ is the Struve function of first order. The integration of Eq. (15) for this case is given by Steel.[17] A table of these functions is given by Watson.[18]

A plot of the line image profile produced by diffraction is included in Fig. 1. The transfer function for a diffraction limited lens may be found from Relations (12) and (16).

$$T(k) = \int_{-\infty}^{+\infty} A(x)\cos(2\pi kx)\,dx \tag{12}$$

$$= \frac{2}{\pi}\left[\cos^{-1} ka - ka\sqrt{1 - (ka)^2}\right] \tag{17}$$

Notice that the transfer function is zero when $ka \geq 1$. This is the case for detail of wavelength $x_o \leq \lambda N$, the true resolution limit at which the modulation in the image goes to zero. The diffraction transfer function for an $f/12$ lens is plotted in Fig. 3. If the curve of Relation (17) is plotted on log paper in terms of $T(k) = T(ka)$, $T \to 0$ as $ka \to 1$, this curve may then be moved along under another piece of similar paper until the 1.0 line on the lower plot coincides with the point $k = 1/\lambda N$ on the upper plot. The curve may be traced through for several values of N as desired. Figure 3 shows also the transfer function as measured on an actual 36-in. focal-length $f/12$ lens. This curve is for an average field angle. On axis the lens is very nearly diffraction limited.

Image Motion

One of the most useful aspects of the use of the transfer functions to predict performance arises from the possibility of expressing such effects as image motion in terms of these relations. The transfer function for vibration, for example, can be given physical meaning by considering the transfer function of a system with the vibration and without it. The function for the vibration is just the ratio of the two. Conversely we may compute a transfer function for vibration of known amplitude and multiply it by the system function to determine the degradation of performance of the system in the presence of vibration.

Let us consider first the case of vibration of a period short compared to the shutter's open time. For vibration of amplitude a and frequency ω the motion is given by

$$x = \frac{a}{2} \sin \omega t \tag{18}$$

while the velocity is

$$v = \omega \frac{a}{2} \cos \omega t \tag{19}$$

Now the exposure is inversely proportional to the velocity of the image,

$$A(x) = \frac{A}{v} = \frac{A}{\cos \omega t} \tag{20}$$

The constant A may be determined by integrating Relation (20) and setting the total exposure equal to unity. Remembering that $\sin \omega t = 2x/a$ from (18) above, one finds

$$A(x) = \frac{2}{a\pi \sqrt{1 - \frac{4x^2}{a^2}}} \tag{21}$$

This image profile is plotted in Fig. 1. (The profile shown is of a line source perpendicular to the direction of vibration.) Once again, Relation II from Jones[5] gives the transfer function.

$$T(k) = \int_{-\infty}^{\infty} A(x) \cos (2\pi k x)\, dx \tag{12}$$

$$= J_o (\pi a k) \tag{22}$$

where J_o is the Bessel function of zero order. The function is plotted in Fig. 4. This is a universal curve and may be adjusted for any special case by sliding it along under a system transfer function. The unity point on the ak axis should be aligned with a point on the scale of the overlying system sheet such that $k = 1/a$ where a is the amplitude of the vibration. The curve may then be traced through and added (multiplied) graphically to the system response.

When the motion of the image with respect to the detector or film is unidirectional and continuous during the exposure, a rather different transfer function results. Errors of image motion compensation or stabilization produce such motion. The profile of a line image for such motion is shown in Fig. 1. The profile is given by

$$A(x) = \frac{1}{a}, -1 \leq a \leq +1 \tag{23}$$

$$= 0, a < -1, a > +1$$

As before, the transfer function is found from Relation (12) and

$$T(k) = \frac{\sin \pi a k}{\pi a k} \tag{24}$$

This curve appears in Fig. 5.

Since other workers may wish to plot master curves for themselves, Table I has been prepared.

TABLE I

Values of $T(k)$

ak	$e^{-2\pi^2 a^2 k^2}$	$J_o(\pi ak)$	$\frac{\sin \pi ak}{\pi ak}$	$\frac{2}{\pi}\left[\cos^{-1} ak - ak\sqrt{1-(ak)^2}\right]$
0.05	0.951	0.994	0.996	0.963
0.10	0.819	0.975	0.983	0.873
0.15	0.640	0.945	0.963	0.810
0.20	0.454	0.904	0.935	0.747
0.25	0.289	0.854	0.900	0.685
0.30	0.170	0.790	0.858	0.623
0.40	0.043	0.646	0.756	0.506
0.45	0.018	0.560	0.699	0.442
0.50	———	0.473	0.636	0.389
0.60	———	0.293	0.525	0.285
0.70	———	0.110	0.368	0.188
0.75	———	0.025	0.300	0.138
0.80	———	———	0.234	0.104
0.90	———	———	0.109	0.038
0.95	———	———	0.052	0.015
1.00	———	———	0	0

The Film

Transfer functions are now available for a variety of photographic materials.[5,19,20]

The curves of Fig. 6 are the transfer functions as obtained by direct measurement by Lamberts.[19] Additional curves could be obtained for other material from the data presented by Eyer.[20] His Table I lists a number of materials and their damping constants m and c. The transfer function is given by

$$T(k) = [(1 - m \times 10^{-6}(2\pi k)^2)^2 + (2\pi k c \times 10^{-3})^2]^{-1/2} \tag{25}$$

in our notation. There seems to be some problem of agreement between various observers, for the constants given by Eyer for Tri-X, Type B give a transfer function displaced nearly a factor of 2 in lines per millimeter from the data of Lamberts for Tri-X. This may arise from a real difference in the two materials used. However, the data for Panatomic-X seems even more discordant.

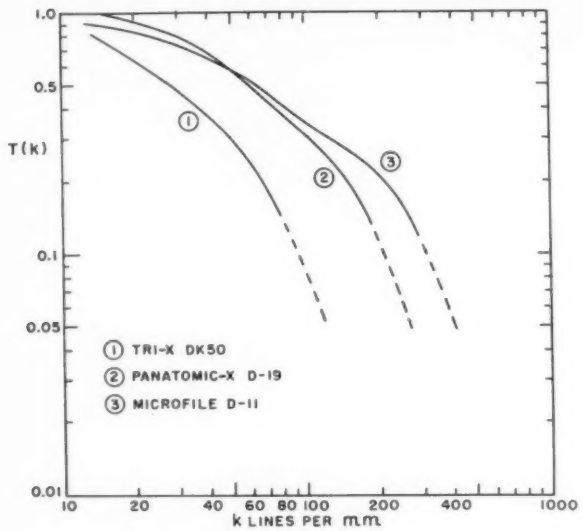


Fig. 6. Transfer functions for photographic films.

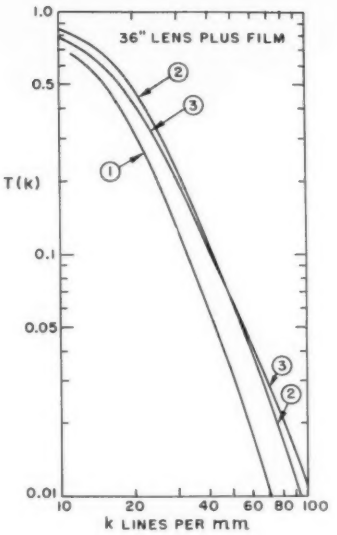


Fig. 7. Transfer functions for lens-film systems.

Detectability

The point at which the modulation actually becomes zero in the image is of little real use to the designer. He is interested in the size of detail which is on the edge of detectability. The effect of grain on detectability has been studied by many investigators[21,22] and a signal-to-noise ratio approach is quite attractive. Here, however, we shall suggest a very much simplified method. When the magnification and illumination are optimized for viewing photographs, the minimum detectable resolution seems to occur at a modulation of between 0.03 and 0.04.[23,24] For the discussion here we have used 0.04 as the limit. A comparison of resolution charts read by eye and traced by a microddensitometer indicates this to be a reasonable value for most observers.

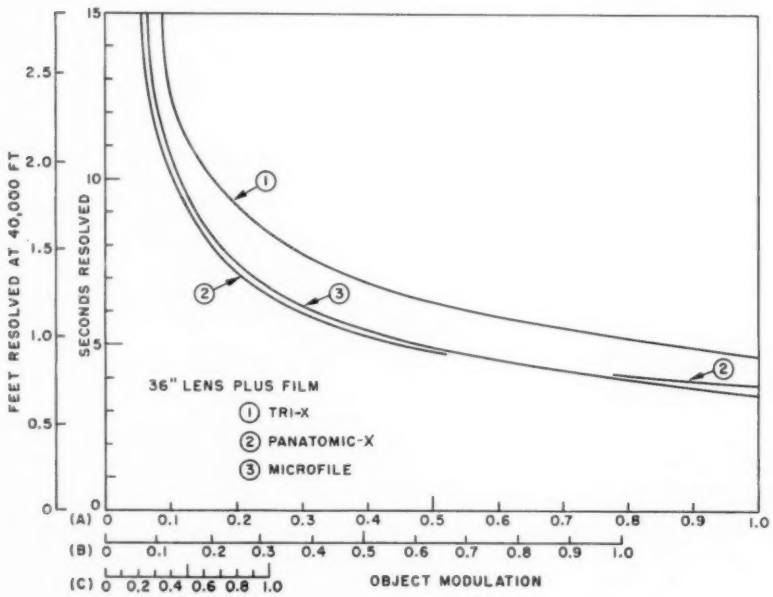


Fig. 8. Predicted system performance.
A — Perfect atmosphere
B — Best atmospheric conditions, 6-mile path length
C — Average conditions through the haze layer

Examples

As an example, let us consider the lens whose transfer function appears in Fig. 3 combined with the films of Fig. 6. The result is shown in Fig. 7. The multiplication of the curves can be carried out by assembling a stack of three sheets of transparent graph paper on a light table. The lowest sheet is Fig. 3. On top of this is Fig. 6 with the coordinates aligned. The third sheet is blank and will become Fig. 7. For each line frequency, the distance from the top of the lens curve is subtracted from each film curve at that line frequency. The resulting points give the three curves of Fig. 7. These are transfer functions for the lens film system. The modulation of the image on the film is

$$M_i = M_o T_s(k) \tag{26}$$

Using a limiting modulation of 0.04 for a detectable detail, the required modulation in the scene becomes

$$M_o = \frac{0.04}{T_s(k)} \tag{27}$$

Figure 8 is a plot of this relation. The resolution in lines per millimeter has been converted to seconds of arc and then to feet on the ground from 40,000-ft altitude. Three scales appear for the object modulation. The (A) scale is the result for objects as seen by the lens. Scale (B) is for objects on the ground under the best atmospheric conditions, where the modulation has been reduced by 0.8 because of atmospheric scattering. The (C) scale indicates the average case in which the scatter has reduced the modulation by 0.25. Before selecting the lens–film combination, the investigation should be extended to include the expected effects of vibration and linear motion. These will be dependent on exposure time, and thus on film speed.

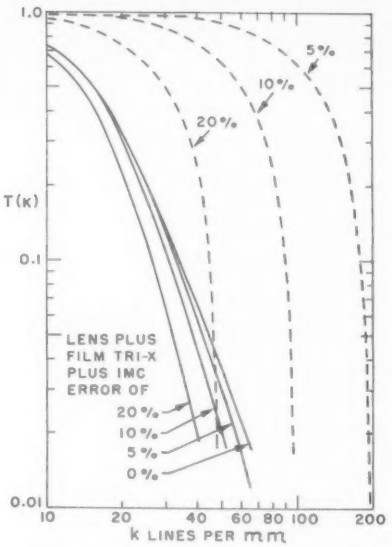


Fig. 9. Transfer functions including image motion compensation.

As a further example, let us consider a case of an error in image motion compensation (IMC). The curve from Fig. 7 for the lens and Tri-X film has been combined with three values of IMC error in Fig. 9. The same transfer method described above was used except that Fig. 5 was moved along in the *ak* direction

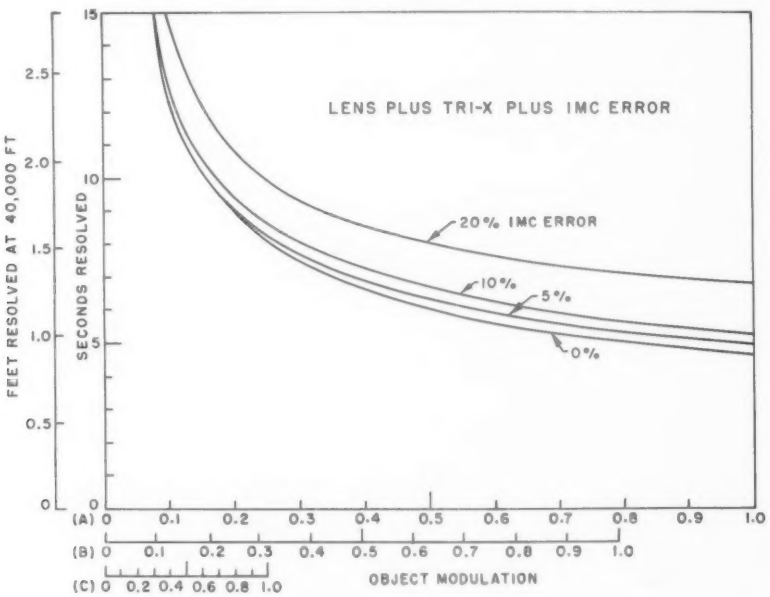


Fig. 10. System performance with image motion compensation errors.

A — Perfect atmosphere
B — Best atmospheric conditions, 6-mile path length
C — Average conditions through the haze layer

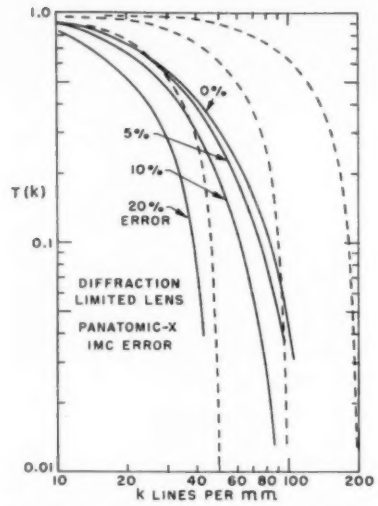


Fig. 11. Transfer functions for a diffraction limited system.

so that the $ak = 1.0$ value of Fig. 5 agreed with the k value of Fig. 7 given by

$$k = \frac{1}{a} = 3.95 \frac{H}{Vtfp} \qquad (28)$$

In this relation

H = altitude in feet
V = speed in feet per second
t = exposure time in seconds
f = focal length in inches
p = percent error of IMC

In the example of Fig. 9, the values $H = 40{,}000$ ft, $V = 666$ ft/sec (400 knts), $t = 1/150$ sec, $f = 36$ in., and $p = 5\%$, 10%, and 15% have been selected. The corresponding k values are 200 lines/mm, 100 lines/mm and 50 lines/mm. The system transfer function may be converted to the expected system performance as was done before. The results are depicted in Fig. 10. It is interesting to note that under average conditions a 5% error in IMC is quite unnoticeable while even 10% would be acceptable under most conditions.

As a final example, the same system maximized by assuming a diffraction limited lens and panatomic film has been combined with various IMC errors. Figure 11 illustrates the transfer functions while Fig. 12 indicates the system performance. Under these conditions a 5% error for an object with a modulation of 0.50 makes about a 10% difference in resolution while a 20% error reduces the resolution by nearly a factor of 2. This is not only true under the best conditions, but holds even when the atmospheric scattering is bad.

Conclusions

A method has been presented for the analysis of performance of photographic systems while the systems are still in the design stage. The fact that the transfer function of an entire system may be expressed as the product of the transfer functions for each component and effect in the system permits the designer to vary and combine these functions as he wishes. Transfer functions for the diffraction limited lens, for vibration, and for linear motion of the lens, and for

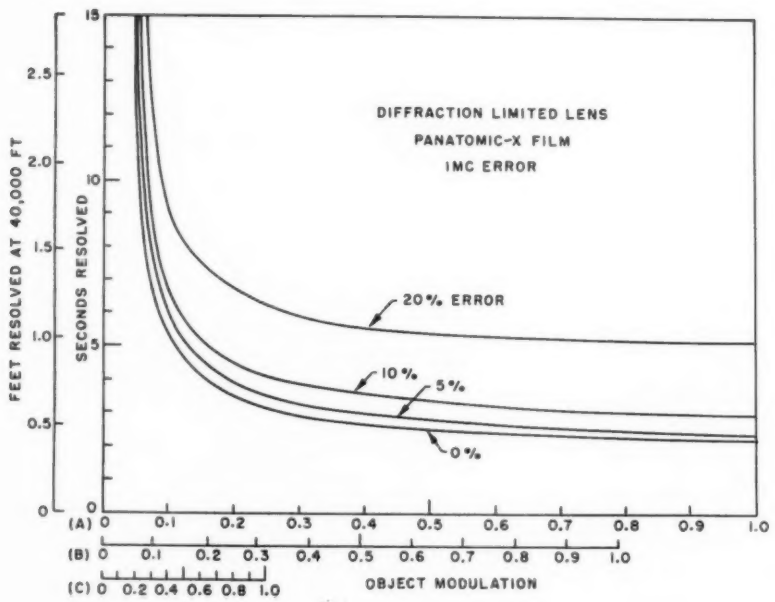


Fig. 12. The effect of image motion compensation errors on the performance of a diffraction limited system.

A — Perfect atmosphere
B — Best atmospheric conditions, 6-mile path length
C — Average conditions through the haze layer

such random displacement of the image as may be produced by atmospheric seeing are developed and presented in useful form. In addition, with the availability of transfer functions for photographic materials the entire system may be analyzed and tolerances may be placed on the various parameters.

Acknowledgments

Through discussion and in bringing some of the many references to the author's attention, Roland V. Shack has been of considerable assistance in the preparation of this paper. In addition, the assistance, through discussion, of G. C. Higgins, R. L. Lamberts, and R. N. Wolfe of the Eastman Kodak Company is gratefully acknowledged. The efforts of Miss Grace Schroeder in preparing the figures and Miss Sherry Augat in preparing the manuscript made the publication possible.

References

1. Schade, O. H., *RCA Rev., 9:* 527 (1948).
2. Elias, P., Gray, D. S., and Robinson, D. Z., *J. Opt. Soc. Am., 42:* 127 (1952).
3. Shack, R. V., *J. Research*, Natl. Bur. Standards, *56:* 245 (1956). (Research Paper 2672.)
4. Eyer, J. A., *J. Opt. Soc. Am., 48:* 938 (1958).
5. Jones, R. Clark, *ibid.*, 934.
6. Eldridge, R. G., and Johnson, J. C., *ibid.*, 463.
7. Carman, P. D., and Carruthers, R. A. F., *ibid., 41:* 305 (1951).
8. Liepmann, H. W., "Deflection and Diffusion of a Light Ray Passing Through a Boundary Layer," *Report SM-14397*, Douglas Aircraft Co., May 16, 1952.
9. Stein, H. A., and Winovich, W., "Light Diffusion Through High-Speed Turbulent Boundary Layers," *NACA RM A56B21*, Ames Aeronatutical Laboratory, Moffett Field, Calif. (1956).
10. Keller, G., Protheroe, W. M., Barnhart, P. E., and Galli, J., "Investigations of Stellar Scintillations and the Behavior of Telescopic Images," ASTIA Document, *AFCRC TR 57-186 AD 117279* (1956).
11. *The Present and Future of Telescopes of Moderate Size*, University of Pennsylvania Press (1957).
12. Polster, H. D., The Perkin-Elmer Corporation *Engineering Report 413* (1955).
13. Schade, O. H., Natl. Bur. Standards *Circular 526:* 175 (1954).
14. Ingelstam, E., Djurle, E., and Sjogren, B., *J. Opt. Soc. Am., 46:* 707 (1956).
15. Herriott, D. R., *ibid., 48:* 968 (1958).
16. Ditchburn, R. W., *Light*, Interscience Publishing Co., New York (1953), p. 64.
17. Steel, W. H., *Rev. opt., 32:* 4 (1953).
18. Watson, G. N., *Theory of Bessel Functions*, Cambridge University Press (1952).
19. Lamberts, R. L., *J. Opt. Soc. Am., 49:* 425 (1959).
20. Eyer, J. A., *ibid., 48:* 938 (1958).
21. Zweig, H. J., Higgins, G. C., and MacAdam, D. L., *ibid., 48:* 926 (1958).
22. Zweig, H. J., *ibid., 46:* 805, 812 (1956); *49:* 238 (1959).
23. Selwyn, E. W. H., *Proc. Physical Soc., 55:* 286 (1943).
24. MacDonald, D. E., Natl. Bur. Standards *Circular 526:* 51 (1954).

PHOTOGRAPHIC SCIENCE AND ENGINEERING
Volume 3, Number 5, September-October 1959

A Method of Contrast Control in Continuous-Tone Xerography

J. T. Bickmore, R. E. Hayford, and H. E. Clark, *Research and Product Development Division, Haloid Xerox Inc., Rochester, N.Y.*

A method of contrast control is described suitable for xerographic printing of continuous-tone photographic negatives. The xerographic plate consists of a thin, photoconductive layer of vitreous selenium deposited on a conductive backing. It is sensitized by charging the selenium layer to a uniform potential. Exposure to an optical image produces a corresponding electrostatic image by partial photoconductive discharge of the surface. This image is developed with an aerosol containing charged black particles, the aerosol passing between the plate and a closely spaced electrode. A bias potential may be applied between the electrode and the conductive backing of the plate. With zero bias potential, exposed areas attract less powder, thus yielding a positive-to-positive reproduction. Conversely, negative-to-positive reproduction is produced when the electrode is biased to a potential higher than the highest potential remaining on the plate after exposure. In the latter case, contrast is dependent upon the relationship between bias potential and initial plate potential. Thus contrast may be continuously varied by means of a simple electrical parameter. Characteristic curves covering the contrast range of photographic printing papers are easily obtained.

Commercial xerographic equipment for high contrast reproduction of line-copy subjects is well known. It is less well known that a considerable degree of progress has been made in continuous-tone xerography, and that xerographic reproductions which compare favorably with silver halide photographic prints are now routinely produced in the laboratory.[1,2] The work to be described is the result of an investigation to find a simple method of contrast control applicable to the xerographic printing of photographic negatives.

To understand the process to be presented, it is necessary to describe the xerographic equipment used in these experiments. The xerographic plate consists of a thin layer of vitreous selenium deposited on a conductive support. The selenium layer is uniformly charged to a potential of several hundred volts by depositing ions formed in a corona discharge. This charge is maintained for long periods in the dark, but is discharged by light in relation to the degree of exposure. Thus, exposure of a charged plate to an optical image forms a corresponding electrostatic image on the plate.

The electrostatic image may be developed by exposing the plate to an aerosol consisting of charged pigment particles. These pigment particles migrate under the influence of the electrostatic fields arising from the image and are deposited on the plate. A conductive electrode roughly the size and shape of the xerographic plate is situated parallel to and close to the xerographic plate during development. Aerosol passes between this development electrode and the xerographic plate. Various electrical potentials may be applied between the conductive back of the xerographic plate and the development electrode. The development electrode serves to orient the electrostatic fields so that they are normal to the surface of the plate in the development zone.

When the potential difference between the development electrode and the conductive backing of the xerographic plate is zero, the degree of development is related inversely to the exposure, since unexposed areas retain charge and thus attract developer powder. Development under these conditions thus results in positive-to-positive reproduction. To obtain negative-to-positive reproduction a potential equal to or higher than the highest potential remaining on the plate after exposure is applied between the development electrode and the conductive backing of the plate. This reverses the electrical fields in the development zone and causes developer powder of polarity opposite to that used for positive-to-positive reproduction to be deposited in direct relation to the degree of exposure. This paper deals mainly with the control of contrast in this negative-to-positive mode of reproduction.

The powder on the developed plate is usually transferred to paper or transparent film for viewing. In the work reported here the powder was transferred to a moistened sheet of dye transfer paper. After soaking the dye transfer paper about 1 min in water and blotting to remove water drops, the dye transfer paper was rolled against the plate using a

Presented at the Annual Conference, Rochester, N.Y., 9 October 1958. Received 12 September 1958; revised 5 August 1959. Work performed under sponsorship of Wright Air Development Center on Contract AF 33 (600)-30785.

pair of low pressure rubber rollers. The paper was then stripped from the plate, allowed to dry, and fixed with clear plastic spray.

Almost every step of the xerographic process offers some opportunity for adjusting contrast. However, by happy coincidence the normal selenium light discharge characteristic combines with the characteristic of normal xerographic development in such a manner that a very useful range of contrasts can be obtained in a completely straightforward manner.

Xerographic Relationships

Continuous-tone xerographic characteristics depend on the characteristics of development and those of the selenium plate. Over a considerable potential range, the potential discharge of the xerographic plate due to light exposure approximates the relationship $\sqrt{V_0} - \sqrt{V} = kE$, where V_0 represents the initial plate potential, V represents the potential after an exposure, E, and k is a constant dependent upon selenium thickness and the units employed. The plates used for this work follow the above relationship for potentials higher than about 50 v. Below this potential the discharge curve departs from the relationship in such a way that plate potential approaches a residual potential of 0 to 15 v. Figure 1 shows a family of light discharge curves. Plate potential is plotted against the logarithm of exposure; each curve represents a different initial potential.

The development parameter which must be discussed is the relationship between the plate potential before development and the resulting optical density of the image after transfer. Limit considerations shed light on basic mechanisms involved. By weighing the powder transferred to paper from a developed metal plate, the relationship between powder mass

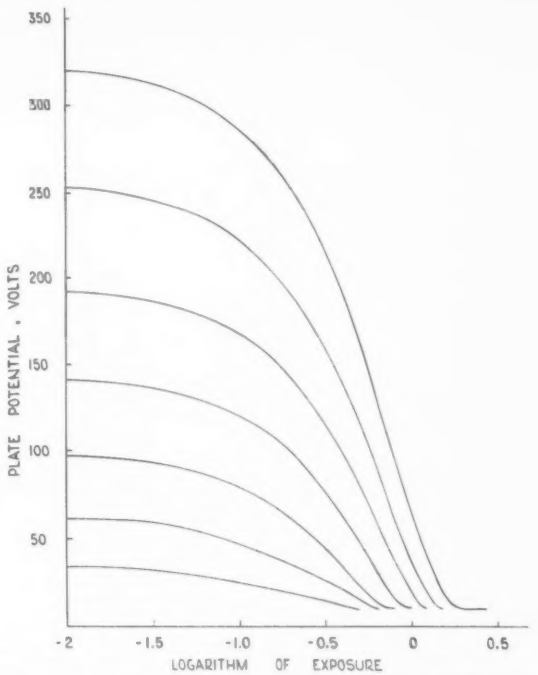


Fig. 1. A family of light discharge curves at a variety of initial potentials illustrating the response of a typical xerographic plate to light exposure. Potentials higher than about 50 v follow the relationship $\sqrt{V} = \sqrt{V_0} - kE$. V_0 and V are the potentials before and after an exposure, E, respectively; k is a constant depending on selenium thickness and the units employed.

per unit area and optical density was determined. When reflection prints (i.e., prints transferred to paper) are made as described above, reflection density is approximately proportional to powder mass per unit area, up to densities near the maximum reflection density of the powder.

The xerographic plate constitutes a parallel plate capacitor with the selenium serving as the dielectric. The top surface of the selenium and the conductive backing act as the parallel plates. Since charge in a capacitor is proportional to potential difference, it follows that the mass of powder deposited per unit area of the plate would be directly proportional to the plate potential before development if the potential of the plate were completely neutralized by charged developer powder. (It is also assumed that the developer powder has a constant specific charge

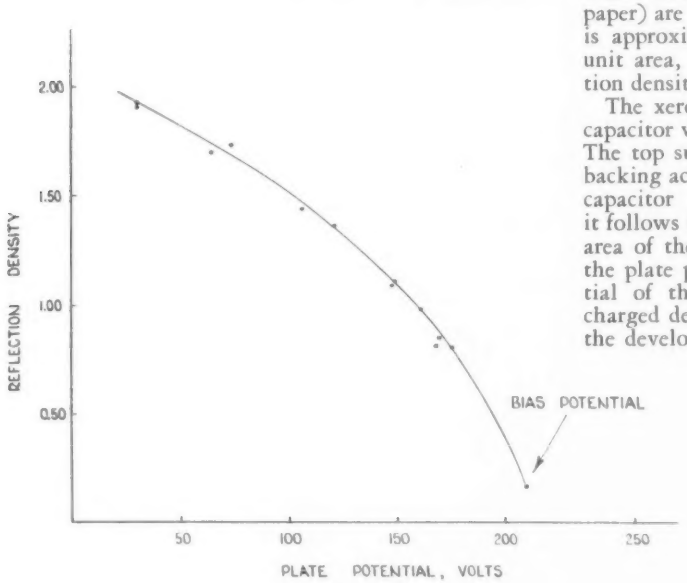


Fig. 2. Relationship between the potential remaining on the xerographic plate after exposure and the resultant reflection density of the transferred and fixed image for typical development conditions. The development electrode was maintained at a potential of 210 v with respect to the conductive plate backing during development.

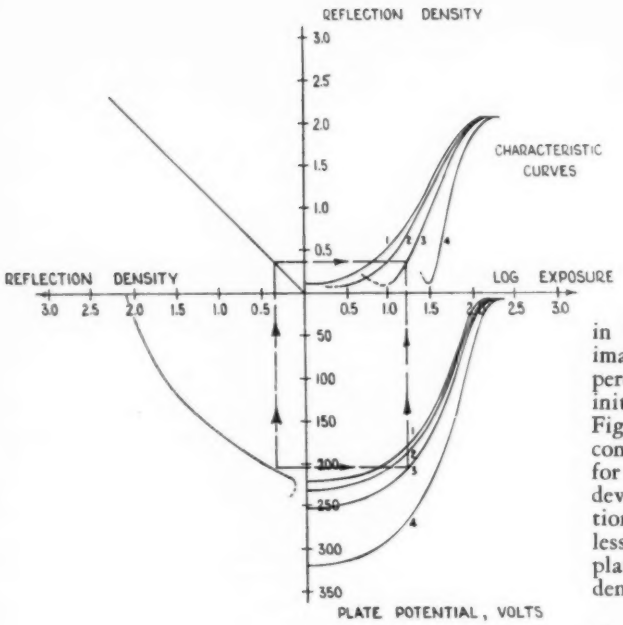


Fig. 3. A graphical method for calculating xerographic characteristics. Light discharge curves are given for four initial potentials in the lower right-hand quadrant. The development curve in the lower left-hand quadrant, representing development with a bias potential of 225 v, is combined separately with each light discharge curve. The straight line in the upper left-hand quadrant relates reflection densities in the lower left-hand quadrant to those in the upper right-hand quadrant. The resulting characteristic curves are shown in the upper right-hand quadrant.

or, if not, that it is deposited in a non-preferential manner.)

Now, since the powder mass per unit area is directly proportional to the resulting optical density, the optical density would be directly proportional to plate potential before development. Under certain conditions of development and transfer, optical density is indeed roughly proportional to plate potential up to the maximum density of the developer powder. The assumption that the electrostatic image is completely discharged in development is, however, generally not true. In the equipment used in the experiments reported here, the electrostatic image is approximately 40% neutralized, with the percentage of neutralization decreasing for higher initial electrostatic fields in the development space. Figure 2 represents a development curve under typical conditions. It should be clear that this curve is for negative-to-positive development conditions. A development curve for positive-to-positive reproduction (with the development electrode bias potential less then the lowest potential on the xerographic plate) is an approximate mirror image, with optical density increasing as plate potential increases.

Theory of Contrast Control Method

Figure 3 illustrates a convenient graphical method for predicting xerographic characteristic curves from light discharge and development curves. This method is used in a manner analogous to the use of the familiar Jones plot in silver halide photography. Light discharge curves and a development curve are plotted in the lower right- and left-hand quadrants respectively. In the upper left-hand quadrant a straight line passing through the origin at a 45° angle is used to relate reflection density values from the development curve directly to reflection density values in the characteristic curve being sought (upper right-hand quadrant).

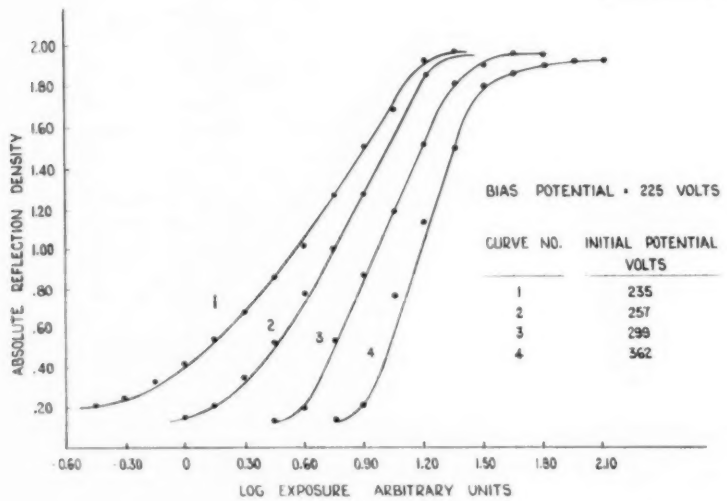


Fig. 4. Experimental xerographic characteristic curves determined from contact exposures to a photographic step tablet. The initial potentials were arbitrarily chosen to approximate photographic enlarging paper characteristics.

The method of contrast control to be described is based on selection of a portion of the electrostatic light discharge curve which has a shape such that when it is combined with the development curve, the desired characteristic is obtained. In Fig. 3, four characteristic curves corresponding to four light discharge curves are drawn. These curves illustrate how different portions of normal light discharge curves are utilized. By setting the initial plate potential equal to the bias potential, the entire light discharge curve is utilized, resulting in a relatively flat characteristic curve. This is illustrated by the curves numbered 1. When initial plate potential is higher than the bias potential, exposure must reduce the plate potential to the bias potential or less. Under this condition, the flattest part of the light discharge curve is eliminated, resulting in a characteristic curve of higher contrast. The greater the relative difference between the initial potential and bias potential, the higher the contrast of the resulting characteristic curve. Curves 2, 3, and 4 represent increasingly higher contrasts obtained in this manner.

One end of the development curve shown in Fig. 3 is dashed. This is to indicate that development utilizing powder of polarity opposite to that of the solid portion of the curve may occur for potentials higher than the bias potential. Whether this actually happens depends on the type of development equipment and whether the developer contains particles of both polarities. Such a characteristic is obtained with the equipment used in the work reported here. Under conditions of actual print making, however, little difficulty is experienced. This is because sufficient exposure to result in a good print from other considerations is generally high enough to leave no potentials higher than the bias potential.

Experimental Results

Characteristic curves were experimentally determined under conditions similar to those shown in Fig. 3. Contact exposures were made using a step-wedge with transmission density steps of 0.15 over the range 0.05 to 3.05. The wedge is surrounded by uniform density of 2.90. Figure 4 shows xerographic characteristic curves obtained using this grey scale. In this example a bias potential of 225 v was used with initial potentials of 235, 257, 299, and 362 v. All other parameters were constant. The contrasts obtained correspond to photographic enlarging paper contrasts 1, 2, 3, and 4 respectively. These curves are similar to the theoretically derived curves of Fig. 3. Characteristics of typical silver halide glossy enlarging papers are shown in Fig. 5 for comparison. These curves were synthesized from the military specification MIL-P-4672A.

Gamma of the process described is a continuous function of initial potential minus bias potential over a considerable range. Thus, intermediate contrasts are readily obtained. Gammas higher than those in these experiments appear to be possible, but no attempt has yet been made to produce them.

From the above discussion it should be clear that contrast is determined by the difference between initial plate potential and bias potential. It has been convenient to hold the bias potential fixed and adjust contrast by varying the initial plate potential, since development potentials remain constant under these conditions. However, a satisfactory system could be devised with constant initial plate potential and contrast control through adjustment of the bias potential. Under equivalent development conditions, i.e., constant maximum reflection density, contrast is essentially independent of initial plate potential for the condition where initial plate potential equals bias potential.

The choice of bias potential is not critical. The considerations that appear important are: (1) that development potentials must be in a range which matches the specific powder charge and plate capacitance in such a fashion that a useful development curve is obtained; (2) that the plate potentials are high enough for efficient and consistent development; and (3) that the plate potentials required for the highest contrast are not so high as to damage the plate. A bias potential of 225 v appears to be near optimum for the system used in this work. With different xerographic plates or different development systems other bias potentials might prove more satisfactory.

Figure 6 is a reproduction of xerographic prints made at different contrasts from a typical negative. These prints were made under conditions roughly equivalent to the conditions used to obtain the characteristic shown in Fig. 4. The bias potential was 225 v and the initial plate potentials were 227, 250, 270, and 315 v. Relative exposures were respectively 2, 3, 4, and 10. Still higher contrasts could be obtained by use of higher initial plate potentials.

One of the most obvious advantages of the system of contrast control described above is simplicity. Contrast may be adjusted by a simple electrical

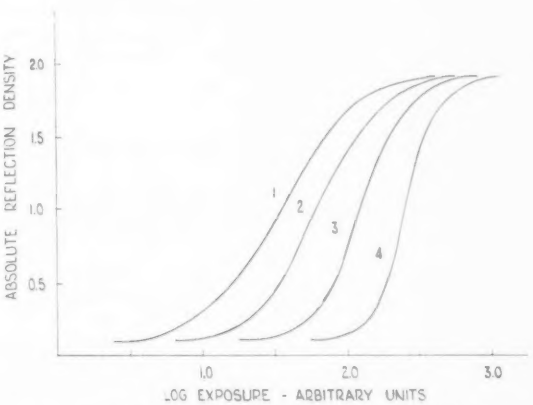


Fig. 5. Typical silver halide enlarging paper characteristics, shown for comparison with Fig. 4. The curves, for glossy papers, were synthesized from the military specification for photographic papers, MIL-P-4672A.

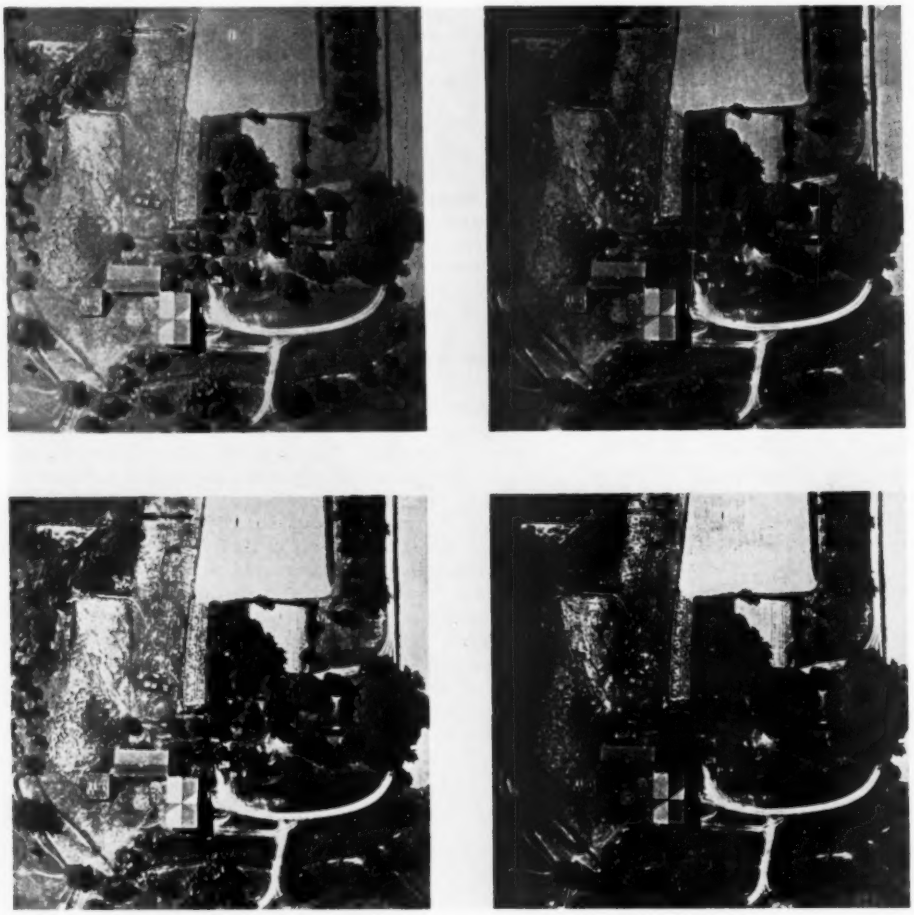


Fig. 6. Xerographic prints of a typical negative, made at four different contrasts. Initial xerographic plate potentials were: upper left, 227 v; upper right, 250 v; lower left, 270 v; lower right, 315 v. The development electrode bias potential was 225 v. Allowance must be made for losses in the reproduction of the original xerographic prints.

parameter coupled with a compensating exposure adjustment. This system should lend itself well to completely automatic printers which automatically adjust for optimum exposure and contrast.

Acknowledgments

The authors wish to acknowledge the cooperation and support of Haloid Xerox Inc. and of the U.S. Air Force. Their permission to publish this material, which is based on work done under U.S. Air Force contract, is sincerely appreciated. Thanks is also given to John H. Dessauer of Haloid Xerox Inc. for his helpful guidance, and to W. J. Burris and E. T. Smith of Haloid Xerox Inc. who have contributed data used in this paper.

References

1. Bixby, W. E., Andrus, P. G., and Walkup, L. E., *Phot. Eng.*, *5:* 195 (1954).
2. Hayford, R. E., and Bixby, W. E., *Phot. Eng.*, *6:* 173 (1955).

PHOTOGRAPHIC SCIENCE AND ENGINEERING
Volume 3, Number 5, September-October 1959

Photothermographic Sensitization of Mercurous Oxalate by Mercurous and Silver Iodides

PAUL B. GILMAN, JR., PHILIP A. VAUGHAN, AND P. A. VAN DER MEULEN, *Ralph G. Wright Laboratory, School of Chemistry, Rutgers, The State University, New Brunswick, N.J.*

Gelatin emulsions containing mercurous oxalate and mercurous iodide have photothermographic sensitivity to visible light. Sensitometric studies show that the sensitization of mercurous oxalate by mercurous iodide is increased considerably by the addition of silver iodide, although the latter compound by itself is not a sensitizer. Sensitometric and x-ray diffraction studies indicate that the sensitization is caused by the photolysis of mercurous iodide to form mercury and mercuric iodide.

In the absence of silver iodide, yellow mercuric iodide is a product of photolysis. If silver iodide is present, red mercuric iodide and/or Ag_2HgI_4 are formed and the efficiency of the photolysis of mercurous iodide is increased.

Sensitometric Study

Mercurous oxalate has been found to be the most promising of a number of compounds studied with respect to photothermographic properties.[1] Although the optical sensitivity of mercurous oxalate is almost entirely in the ultraviolet region of the spectrum, it has been found that adsorption of certain dyes can cause sensitivity to visible light.[2] In no case in the present study, however, was this induced sensitivity as great as the response of undyed mercurous oxalate to ultraviolet light. Therefore, we have investigated the photothermographic sensitization of mercurous oxalate by mercurous and silver iodides. These materials were selected because of their known photosensitivity and because mercurous iodide absorbs visible light.

Preparation of Emulsions

Each emulsion used in this study consisted of a total of 14 grams of inorganic solids precipitated in the absence of gelatin, washed by decantation, and dispersed in a solution of 37.5 grams of gelatin (Eastman Kodak No. 1099, Purified Calfskin Gelatin) in 150 ml of water. The emulsions were made up to a total of 500 grams by the addition of distilled water and were passed twice through a hand homogenizer. They were then placed in a refrigerator to gel overnight and were coated on glass plates the day after preparation.

To be presented at the 1959 National Conference, Chicago, Ill., 26–30 October. Received 5 June 1959.

The work described is based on a thesis submitted to the Graduate Faculty of Rutgers, The State University, by Paul B. Gilman, Jr., in partial fulfillment of the requirements for the degree of Doctor of Philosophy. The work was carried out under contract AF18(600)-1150, Air Force Office of Scientific Research, Washington 25, D.C., and the report is designated Technical Document No. 59-67 and Astia Document No. 217 410.

To coat, the gelled emulsions were first warmed to 40°–50° C on a steam bath, at which temperature the emulsions flowed easily. Five-milliliter portions were spread evenly over $3\frac{1}{4}$ by 4-in. glass plates, which were then chilled on a leveled metal plate which was cooled to 8° C. The emulsions set within 2 min, and the plates were placed in a refrigerator to dry.

To obtain the mercurous oxalate-mercurous iodide precipitates, the calculated amount (based on 14 grams of total precipitate) of freshly recrystallized $Hg_2(NO_3)_2$ was dissolved in approximately 125 ml of distilled water plus 6 ml of 6 N HNO_3. This was added, with rapid stirring, to a solution of 52 grams of $K_2C_2O_4 \cdot H_2O$ and the required amount of KI in 160 ml of distilled water. It was assumed that all of the iodide would be precipitated because of the low solubility product of Hg_2I_2. The excess oxalate is necessary to obtain a sensitive emulsion.

To prepare $Hg_2C_2O_4$–Hg_2I_2–AgI precipitates, the following four solutions were first prepared: (1) the required amount of $Hg_2(NO_3)_2$ dissolved in 125 ml of water plus 6 ml of 6 N HNO_3; (2) 52 grams of $K_2C_2O_4 \cdot H_2O$ dissolved in 160 ml of water; (3) the required amount of $AgNO_3$ dissolved in 150 ml of water; and (4) the required amount of KI in 150 ml of water. The amounts of $Hg_2(NO_3)_2$, $AgNO_3$, and KI were based on a final weight of 14 grams of precipitates and a predetermined final composition. Solution (1) was first added to solution (2) to precipitate $Hg_2C_2O_4$. Then solution (3) was added to solution (4) and the resulting mixture was added to the $Hg_2C_2O_4$ precipitate. It was assumed that the excess iodide ion attacks $Hg_2C_2O_4$ to form Hg_2I_2.

Light Exposures and Development

The monochromator of a Beckman DU Spectrophotometer was used to obtain quantitative exposures

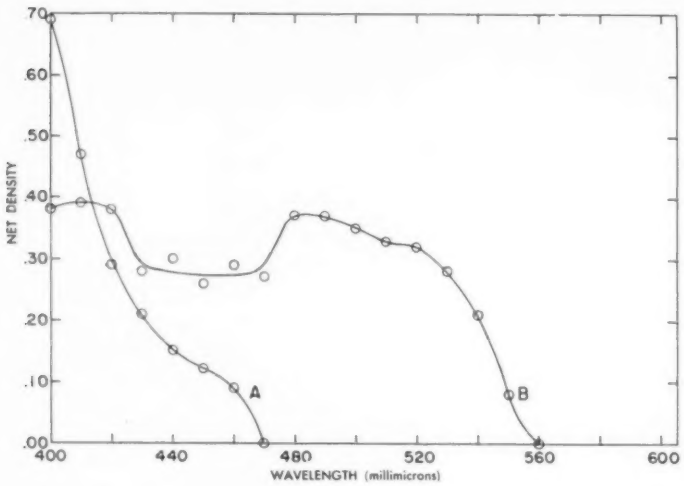


Fig. 1. Spectral sensitivity of mercurous oxalate (Curve A) and 84% mercurous oxalate – 16% mercurous iodide (Curve B) emulsions. Equal energy exposures of 7920 μw/sq cm.

at known wavelengths. The energy output of the system as a function of wavelength was determined by means of a calibrated bismuth-silver Eppley thermopile. Although the intensity could be varied by changing the slit width, the instrument was always operated so that intensity incident on the slide was 132 μw/sq cm. Different exposures were obtained by varying the time of exposure.

The exposed slides were developed by heating them to 105° C for 4 min. This was accomplished by means of an aluminum oven containing a slot into which the slide could be inserted. The oven unit was wrapped with asbestos cloth, wound with resistance wire, and covered with refractory cement. The temperature was controlled by means of a mercury thermoregulator which was imbedded in the unit. The temperature of the slides during development was measured by means of a calibrated thermocouple.

Experimental Results

The spectral sensitization of mercurous oxalate was investigated with an emulsion of 16 mole % Hg_2I_2 and 84 mole % $Hg_2C_2O_4$. For comparison, an emulsion of pure $Hg_2C_2O_4$ was also examined. Slides were exposed to equal energies (7920 μw-sec/sq cm) of light of various wavelengths; the results are given in Fig. 1. It will be noted that sensitization occurs well into the visible and that a maximum occurs at 480–490 mμ.

A sensitometric study was made of the effect of composition on the sensitivity of Hg_2I_2 – $Hg_2C_2O_4$ emulsions to light of 490 mμ wavelength. The data obtained are summarized in Fig. 2, which gives the net image density as a function of exposure time for emulsions of various compositions. It is clear that Hg_2I_2 is an effective sensitizer; the most sensitive emulsion was that containing 16 mole % Hg_2I_2.

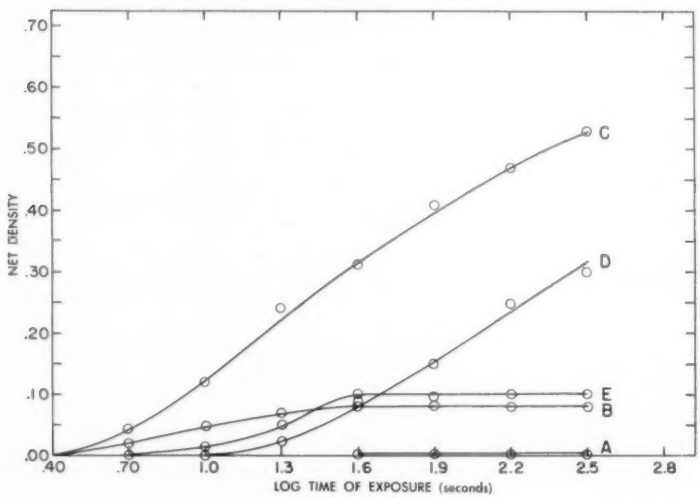


Fig. 2. Photothermal sensitivity of mercurous iodide – mercurous oxalate emulsions. Wavelength — 490 mμ; intensity — 132 μw/sq cm; slit-width — 1.5 mm.

Curve	Mole % $Hg_2C_2O_4$	Mole % Hg_2I_2
A	98	2
B	92	8
C	84	16
D	60	40
E	0	100

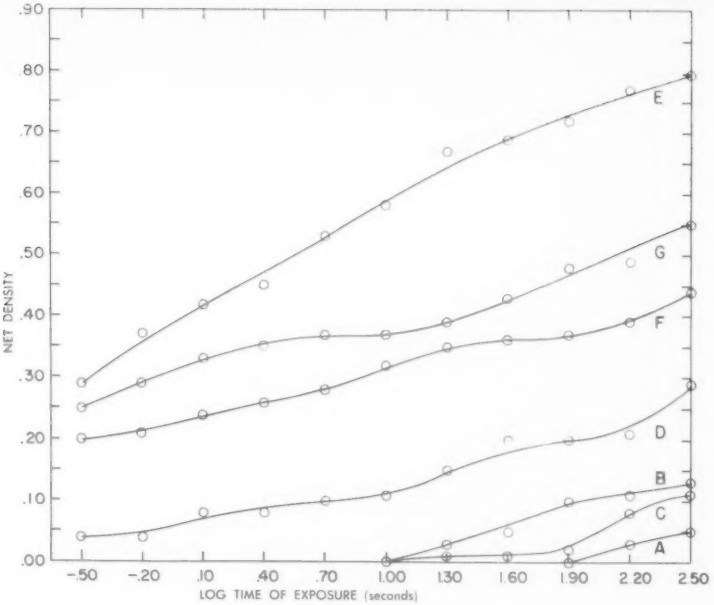


Fig. 3. Photothermal sensitivity of mercurous oxalate – mercurous iodide – silver iodide emulsions. Wavelength — 490 mμ; intensity — 132 μw/sq cm; slit-width — 1.5 mm.

Curve	Mole % $Hg_2C_2O_4$	Mole % Hg_2I_2	Mole % AgI
A	92	4	4
B	84	8	8
C	60	35	5
D	60	20	20
E	43	7	50
F	40	30	30
G	30	20	47

Although AgI itself does not sensitize the photothermal decomposition of $Hg_2C_2O_4$, it was found that this compound enhances considerably the sensitizing action of Hg_2I_2. Several different emulsions containing $Hg_2C_2O_4$, Hg_2I_2, and AgI were prepared and tested for photothermal sensitivity. The data are shown in Fig. 3. The sensitivity of the best emulsion (50 mole % AgI, 7% Hg_2I_2, 43% $Hg_2C_2O_4$) to light of 490 mμ wavelength is comparable to that of pure mercurous oxalate emulsion to light of 254 mμ wavelength and is considerably greater than the sensitivity of any of the dyed emulsions reported by van der Meulen and Brill.[2]

It was noted that mercurous oxalate emulsions sensitized with Hg_2I_2 or Hg_2I_2 and AgI were very sensitive print-out systems. With the most sensitive three-component emulsion (see above), and for an exposure of 10 sec, the net density of the print-out image was approximately one tenth that of the final photothermal image, and for an exposure of 100 sec this factor was one half.

To compare the spectral sensitivity of a $Hg_2C_2O_4$ emulsion sensitized with Hg_2I_2 and AgI with one sensitized with Hg_2I_2 only, wedge spectrograms were made on coated slides with a Hilger quartz spectrograph. The spectral distributions of sensitivity of

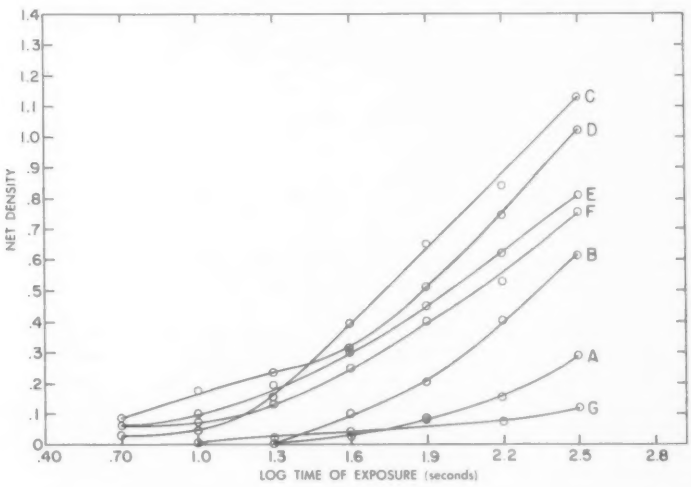


Fig. 4. Print-out sensitivity of mercurous iodide – silver iodide emulsions. Wavelength — 490 mμ; intensity — 132 μw/sq cm; slit-width — 1.5 mm.

Curve	Mole % Hg_2I_2	Mole % AgI
A	100	0
B	99.5	0.5
C	99.0	1.0
D	90.0	10.0
E	68.0	32.0
F	26.0	74.0
G	6.0	94.0

both of these systems were almost identical and were very similar to the reflectance spectrum of Hg_2I_2. It thus appears that sensitization is due to absorption of light by Hg_2I_2, and AgI increases the efficiency of the photolysis of this compound.

Photolysis of Mercurous Iodide-Silver Iodide Mixtures

To gain insight into the mechanism of the photothermal sensitization of $Hg_2C_2O_4$ by Hg_2I_2 and AgI, we have studied the photolytic decomposition of Hg_2I_2 and Hg_2I_2 – AgI mixtures by sensitometry and by x-ray diffraction.

Sensitometric Studies

Emulsions containing Hg_2I_2 and AgI in various proportions were prepared and coated on glass slides by essentially the same technique that was described in the first part of this paper. The total weight of precipitate was 14 grams for 500 grams of emulsion. The print-out (no development) sensitivity of these emulsions was examined by exposing them for various times to light with a wavelength of 490 mμ and intensity of 132 μw/sq cm. The results of this study are shown in Fig. 4. It is seen from these results that emulsions containing from 1.0 to 74 mole % AgI are considerably more photosensitive than a pure Hg_2I_2 emulsion. An emulsion containing pure AgI has no measurable sensitivity under these conditions.

When the Hg_2I_2 – AgI emulsions were heated after exposure, a small increase in density resulted. The density increase was greatest for low exposures. It was found that continued heating actually destroyed the print-out image so that the initial light-sensitivity was restored. It was later found that a thermally irreversible image could be obtained by chemical development in 1:2 Dektol.[3]

X-Ray Diffraction Studies

It is apparent from the sensitometric studies on $Hg_2C_2O_4$ – Hg_2I_2, $Hg_2C_2O_4$ – Hg_2I_2 – AgI, and Hg_2I_2 – AgI systems that the mechanism of the photothermal sensitization of $Hg_2C_2O_4$ by Hg_2I_2 and Hg_2I_2 – AgI mixtures is intimately connected with the products of the photoreaction of Hg_2I_2 and the manner in which these are affected by the presence of AgI. We have investigated these problems by following the photolysis of Hg_2I_2 and Hg_2I_2 – AgI mixtures by means of x-ray diffraction patterns. Emulsions were prepared and coated on glass slides by the methods already described. The x-ray powder patterns of these emulsions could easily be obtained with a North American Philips diffractometer; the coated slide was simply placed in the sample holder and the instrument was operated in the normal fashion. Ni-filtered CuKα radiation of wavelength 1.542 A was used in every case.

The diffraction patterns (intensity vs. 2θ) of the pure materials of interest in the investigation were obtained and are given in Fig. 5. These patterns were obtained from emulsions of the compounds in gelatin, except in the case of the yellow (unstable) form of HgI_2. The latter compound was obtained by boiling a mixture of red HgI_2 and vaseline. If kept in the dark, the yellow modification thus formed will not change back to the red form in a year.[4] This mixture with vaseline was used to obtain the diffraction pattern of yellow HgI_2. A comparison of the interplanar (d/n) spacings corresponding to the principal diffraction lines with those reported in the literature for these compounds is given in Table I. Good agreement is obtained in each case.

TABLE I

Compound	*d*, A		Reference No.	Relative intensity
	This work	Literature		
Hg_2I_2	4.54	4.54	5	20
	3.49	3.48		100
	2.90	2.90		20
	2.23	2.23		50
AgI	3.72	3.74	6	100
	2.27	2.29		60
	1.94	1.95		20
HgI_2 (yellow)	6.94	—		100
	4.16	—		20
	3.82	—		20
	3.45	—		20
HgI_2 (red)	6.21	6.20	5	40
	4.12	4.12		60
	3.58	3.58		100
	3.01	3.01		35
	2.76	2.76		25
	2.19	2.19		70
Ag_2HgI_4	5.67	5.64	7	5
	4.48	4.47		5
	3.66	3.65		100
	2.24	2.23		50
	1.90	1.90		30

The photolysis of mercurous iodide in a gelatin emulsion was studied by exposing a coated slide to the light level which existed in the laboratory and obtaining diffraction patterns from the slide at intervals of one day. Diffraction patterns obtained after 2 days and after 5 days of exposure are given in Fig. 6. Comparison with the diffraction patterns of the pure compounds shows quite clearly that the yellow form of HgI_2 is a product of the photolysis of Hg_2I_2. A detectable amount of red HgI_2 is observed after 3 days of exposure and this form becomes predominant after 5 days. However, it is reasonable to assume that this results from a transformation of the unstable yellow form.

To study the photolysis of the Hg_2I_2 – AgI system, an emulsion of a mixture containing 74 mole % AgI and 26 mole % Hg_2I_2 was prepared and coated on a slide. Diffraction patterns of this slide before and after a 2-day exposure are given in Fig. 6. Comparison with the diffraction patterns of the pure compounds shows that only the red form of HgI_2 is observed from the photodecomposition of Hg_2I_2 in this mixture; the strong peak at 12.75° characteristic of yellow HgI_2 is completely absent. One can also see from Fig. 6 that the photolysis of Hg_2I_2 is much more rapid in the presence of AgI.

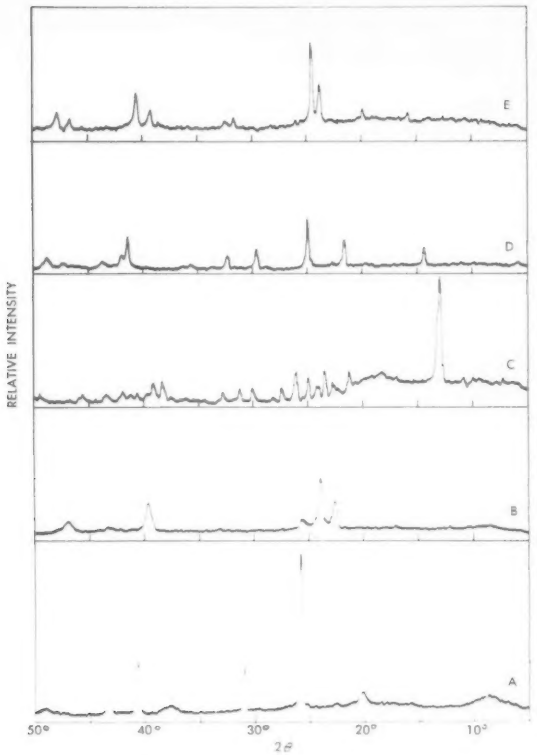


Fig. 5. X-ray diffraction patterns of compounds: A — Hg_2I_2; B — AgI; C — HgI_2 (yellow); D — HgI_2 (red); E — Ag_2HgI_4.

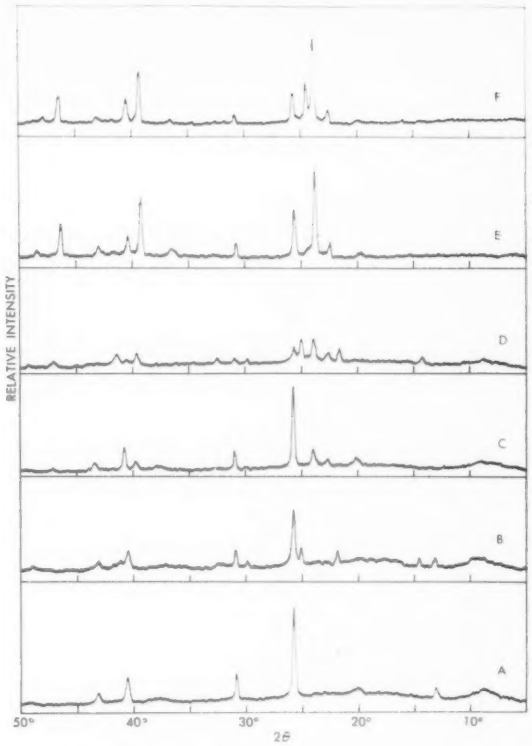


Fig. 6. X-ray diffraction study of the photolysis of mercurous iodide and mercurous iodide – silver iodide mixtures.
A — Mercurous iodide emulsion, exposed 2 days
B — Mercurous iodide emulsion, exposed 5 days
C — 26 mole % Hg_2I_2 – 74 mole % AgI emulsion, unexposed
D — 26 mole % Hg_2I_2 — 74 mole % AgI emulsion, exposed 2 days
E — Mixed powders of Hg_2I_2 and AgI, exposed 1 day
F — Mixed powders of Hg_2I_2 and AgI, exposed 4 days

The effect of light on mixed powders of Hg_2I_2 and AgI was also studied. In this case no gelatin was added and the sample was held in the metal sample holder normally used with the x-ray diffractometer. Diffraction patterns obtained after exposures of this mixture for one and for 4 days are shown in Fig. 6. In this case, neither the red nor the yellow form of HgI_2 can be identified as a product. Instead, a new peak is observed at 24.34° which increases in height with increasing exposure. This was identified as the most intense peak in the diffraction pattern of the complex compound Ag_2HgI_4 (see Fig. 5). Possibly the formation of this compound from HgI_2 and AgI is inhibited when gelatin is present, but its presence in detectable amounts may be dependent on the relative concentrations of Hg_2I_2 and AgI.

To see if the reactions which were demonstrated in the above experiments actually occur in photothermographic emulsions, the photolytic and photothermographic reactions in $Hg_2I_2 - Hg_2C_2O_4$, and $Hg_2I_2 - AgI - Hg_2C_2O_4$ emulsions were followed by x-ray diffraction. In the case of a 16% Hg_2I_2 – 84% $Hg_2C_2O_2$ emulsion, an exposure of 2 days resulted in the appearance of the HgI_2 (yellow) diffraction line at 12.75° and a decrease in the intensities of the Hg_2I_2 lines. Development by heating for 4 min at 105° C resulted in almost complete obliteration of the $Hg_2C_2O_4$ lines, restoration of the Hg_2I_2 lines, and obliteration of the HgI_2 (yellow) line.

In the case of a 20% Hg_2I_2 – 47% AgI – 33% $Hg_2C_2O_4$ emulsion, an exposure of 8 hr resulted in the appearance of a line at $2\theta = 24.34°$ ($d/n = 3.66$ A) which is the principal line in the powder pattern of Ag_2HgI_4. Development by heating again resulted in the obliteration of the $Hg_2C_2O_4$ lines and the restoration of Hg_2I_2 and AgI at the expense of Ag_2HgI_4. No yellow-HgI_2 lines were observed in this case.

Discussion

The results indicate that one of the products of the photolysis of Hg_2I_2 (probably Hg) catalyses the thermal decomposition of $Hg_2C_2O_4$. The enhanced sensitization obtained by adding AgI can then be explained since it was demonstrated that AgI increases the efficiency of the photolysis of Hg_2I_2. It is possible to explain all of the observed effects, at least qualita-

tively, by a consideration of the following reactions:

(1) $Hg_2I_2 + h\nu \rightarrow HgI_2$ (yellow) + Hg

(2) HgI_2 (yellow) + Hg $\rightarrow Hg_2I_2$

(3) HgI_2 (yellow) + $2AgI \rightarrow Ag_2HgI_4$

(4) HgI_2 (yellow) + $Ag_2HgI_4 \rightarrow HgI_2$ (red) + Ag_2HgI_4

(5) HgI_2 (red) + Hg $\rightarrow Hg_2I_2$

(6) Ag_2HgI_4 + Hg $\rightarrow Hg_2I_2 + 2AgI$

In order to account for the observations by means of these reactions it is only necessary to assume that the reversal of the photolysis to form Hg_2I_2 proceeds faster by Reaction (2) than by (5) and (6). Thus AgI acts by removing the reactive yellow form of HgI_2 to form Ag_2HgI_4 by Reaction (3), or red HgI_2 by Reaction (4). It is also possible that AgI and/or Ag_2HgI_4 simply act as acceptors for Hg^{++} and I^- as they are formed by the photolytic process. It is therefore not essential to assume that yellow HgI_2 is formed in the presence of these compounds. Thus, the net results of Reactions (1), (3), and (4) can be achieved by the following sequence of events:

(1) Hg^{++}, $2I^-$ (in Hg_2I_2), and Hg produced by photolysis

(2) Migration of Hg^{++} and $2I^-$ (by diffusion or electron transfers) to an adjacent grain of AgI or Ag_2HgI_4

(3) Acceptance of Hg^{++} and $2I^-$ by AgI to form Ag_2HgI_4, or acceptance of Hg^{++} and $2I^-$ by Ag_2HgI_4 to form a solid solution containing excess HgI_2

(4) Migration of Hg^{++} and I^- in the Ag_2HgI_4 – HgI_2 solid solution to a growing crystal of red HgI_2

This mechanism would account for the sensitization by AgI of the photolysis of Hg_2I_2 by reducing the recombination of Hg^{++} and I^- ions with Hg to form Hg_2I_2. It is also in accord with the structure[8,9] of Ag_2HgI_4 and the rather large mobility of positive ions in this compound.[10]

References

1. van der Meulen, P. A., and Countryman, R. C., *Phot. Eng.*, *4:* 104 (1953).
2. ——— and Brill, R. H., *Phot. Sci. and Eng.*, *2:* 121 (1958).
3. ——— and Gilman, P. B., Jr., U.S. Pat. 2,874,047 (1959).
4. Kastle, J. H., and Reed, J. V., *Am. Chem. J.*, *27*: 209 (1902).
5. Huggins, M. L., and Magill, P. L., *J. Am. Chem. Soc.*, *49:* 2357 (1927).
6. Hanawalt, J. D., Rinn, H. W., and Frevel, L. K., *Ind. and Eng. Chem., Anal. Ed.*, *10:* 457 (1938).
7. Frevel, L. K., and North, P. P., *J. Applied Phys.*, *21:* 1039 (1950).
8. Ketelaar, J. A. A., *Z. Krist*, *80:* 190 (1931).
9. ———, *ibid.*, *87:* 436 (1934).
10. ———, *Trans. Faraday Soc.*, *34:* 874 (1938).

PHOTOGRAPHIC SCIENCE AND ENGINEERING
Volume 3, Number 5, September-October 1959

An Edge Effect in Color Films Caused by Distortion of the Developed Image when a Hardening Bleach Is Used

HOBSON J. BELLO, JR., AND DAAN M. ZWICK, *Research Laboratories, Eastman Kodak Company, Rochester, N.Y.*

An edge-effect phenomenon occurring in color films is illustrated. The source of the effect is shown to be a distortion of the developed image resulting from differential hardening of gelatin in image and non-image areas during bleaching and subsequent dislocation during drying. Variables affecting this effect are described. The photographic effect of this phenomenon is illustrated for Eastman Color Intermediate Film, Type 5253.

At a relatively sharp boundary between two areas of a negative having a large difference in density, the dark area immediately adjacent to the boundary may have a density higher than that in the extended dark area, and the light area close to the boundary may have a lower density than the extended light area. This increase in density at the edge of the dark area is called "the border effect." The decrease in density at the edge of a light area is called "the fringe effect." These two effects are frequently referred to together as "edge effects." Such effects may be illustrated by means of a microdensitometer trace where density is plotted against distance across a boundary (Fig. 1). The distances involved may be from the order of microns to millimeters, depending upon particular conditions.

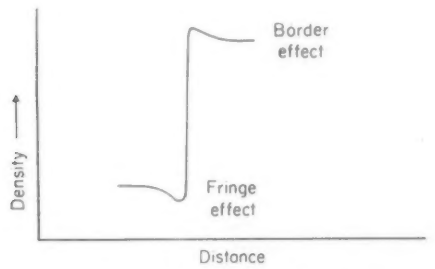


Fig. 1. Microdensitometer trace across a sharp boundary between high and low density areas.

These edge effects have been known for a long time and have been extensively studied by Valenkov[1] and Wolfe and Barrows.[2] The local density differentials have been shown to be due to variations in degree of development associated with local differences in concentrations of fresh developer and development reaction products which frequently restrain development. Compared with the interior regions, there is at the edge of a heavily exposed and developing area a greater influx of fresh developer from (and more diffusion of development by-products into) the adjacent lightly exposed and developing region. This band can, therefore, develop to a higher density than is possible in the interior regions of the image. At the lightly exposed side of the boundary, the higher concentration of restraining development products coming from the immediately adjacent, heavily developing area causes a repression of development and consequently less density than in the area farther away from the boundary. Ross[3] showed that development effects can also produce gelatin hardening differences which cause image distortions.

The purpose of this paper is to report the existence of similar edge effects which, however, are not the result of the development reaction. These edge effects are a result of differential hardening across an exposure edge rather than differential development across the edge. Such differential hardening may occur in negative color processes, for example, where the bleaching of the silver image is accompanied by a local tanning of the gelatin.

The process for a negative or positive color material generally includes treatment in color developer, stop bath, bleach bath, and fixer; the material is then washed and dried. There are also washes or rinses between some of these steps. In some color processes, the stop bath and the fixing bath may provide general hardening of the film in addition to their primary functions. If the bleach used in the color process is a non-tanning bleach, such as a bromide-ferricyanide formula, no differential hardening between image and non-image areas occurs. However, if an acid dichromate formula is used, the gelatin is locally tanned in the area where silver is being bleached (the image area) and is tanned less, or not at all, in lower density or unexposed areas. The differential in hardening between areas of different

Communication No. 2025 from the Kodak Research Laboratories. Received 4 June 1959.

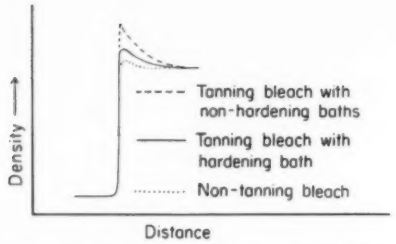


Fig. 2. Microdensitometer traces across sharp boundaries at various conditions of differential tanning.

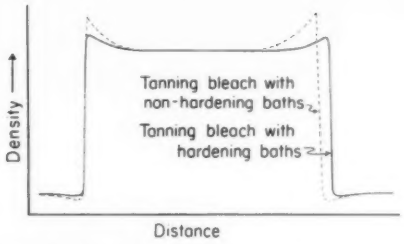


Fig. 3. Microdensitometer traces across sharp line images at two conditions of differential tanning.

density can be increased if there is no general hardening of the film by such solutions as the stop bath or the fixer. In this case, the only hardening action will come from tanning effects in the bleach and possibly the developer, both of which tan in proportion to image.

A comparison of the edge effects obtained with a non-tanning bleach, a tanning bleach with hardening stop and fixing baths, and a tanning bleach with non-hardening baths shows quite clearly (Fig. 2) the dependence of this phenomenon on differential hardening. Here the development conditions were constant and the only variables were the tanning properties of the bleach and the hardening characteristics of the stop and fixing baths.

An insight into the mechanism of the formation of these edge effects can be gained if an entire image rather than just an edge is examined with a microdensitometer (Fig. 3). Here a trace has been made across the width of a millimeter-wide line. The broken line in the figure represents a condition of extreme hardness differential between the image and the surrounding area, and the solid line indicates the condition of no hardness differential. Besides the presence of the "ears" or edge effect, it is evident that a change in the actual width of the image occurs, a contraction or compression which apparently results from a physical distortion of the image.

The nature of this distortion was determined more exactly by microscopic examination of the differentially hardened images while they were drying. By using low-angle grazing illumination to put the surface texture into strong relief, it was possible to observe the sequence of drying in the image and non-image areas. The apparent sequence is illustrated schematically in Fig. 4. When the film is wet at the end of the process, the thickness of image and that of non-image areas appear to be equal. However, the image area, which is hardened during bleaching, appears to dry more rapidly, decreasing its thickness until it is depressed noticeably below the adjacent non-image area. The non-image area may be drying down during this time, but the image area dries either much more rapidly or much sooner.

As drying progresses, the unhardened, non-image area dries down, first becoming as thin as the image area, and eventually much thinner, leaving a raised image. At the end of the drying cycle, there is a definite, final shrinkage of the gelatin in the unhardened areas, which leaves the image standing out quite sharply from the unexposed areas.

The steps in the drying sequence present the idea that the distortion which occurs is that of the exposed, hardened area shrinking together, owing to greater cohesive forces, stretching the softer, unexposed, unhardened areas, and compressing the edge of the exposed area. A buckling at the edge results, with more thickness and optical density at the exposed side of the edge, and less thickness and optical density at the unexposed side of the edge, when compared with thickness and optical density at distances well removed from the edge.

Cross-sections of tanned and non-tanned line images were measured at several places relative to their edges, by use of a Filar micrometer head on the microscope to study further the shape and degree of distortion (Fig. 5). The measurements are summarized in Table I.

It is evident that, away from the edge, the film has approximately the same thickness in the image area in both processes. Similarly, the non-image area reaches the same thickness well away from the edge. At the edge, however, the differential between

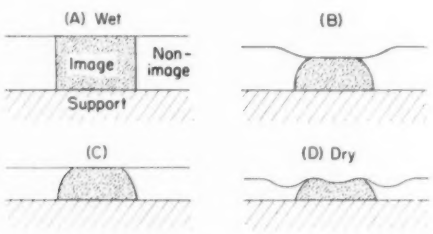


Fig. 4. Schematic diagram showing the apparent sequence of drying in image and non-image areas for a condition of extreme differential tanning.

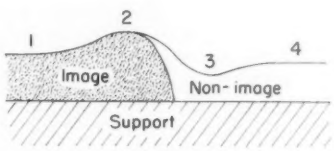


Fig. 5. Schematic diagram of an exposure edge showing the shape and degree of distortion.

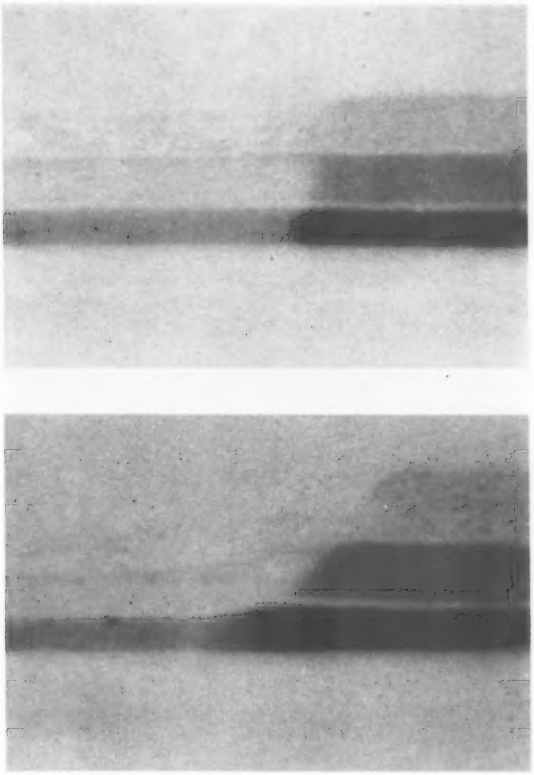


Fig. 6. Photomicrographs of exposure edges in a color film having the normal order of layers, i.e., cyan next to the base, magenta in the middle and yellow on top. Top: non-tanning process. Bottom: extreme condition of tanning.

maximum and minimum thicknesses is obviously much greater at the condition which produces the greater hardness differential.

Another aspect of the contraction of the hardened image, at the expense of unhardened non-image areas, is the differential shrinkage of images in a multilayer film depending on the distance of the image layer from the support. In the photomicrographs of Fig. 6, the distortion in the position of the exposure edge of the several layers is easily visible. At the extreme condition of differential tanning, the cyan, magenta, and yellow images are displaced relative to a common edge at the gel–support interface. This is a logical result of a cohesive shrinking of an image, since the bottom layer is firmly attached to a non-contracting

TABLE I

	Thickness in microns measured at positions indicated in Fig. 5			
	1	2	3	4
Tanned image	17.6	20.4	14.5	16.8
Non-tanned image	17.5	18.0	16.0	16.8

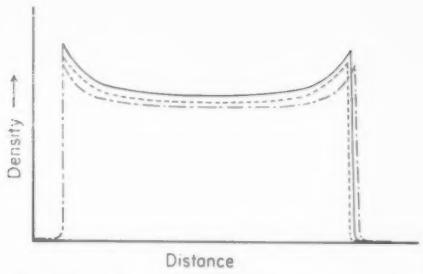


Fig. 7. Neutral line image traced with
——— Green light – – – Blue light —·—·— Red light

support, and the upper layers are increasingly removed from this restraint.

The magnitude of the differential image size produced in this manner is indicated by red-light, green-light, and blue-light microdensitometer traces of a neutral line image (Fig. 7).

The cyan image, as indicated by the red-light trace, is considerably wider than the yellow image, indicated by the blue-light trace, and the magenta image is intermediate in size. The extreme condition of differential hardening was used to obtain a difference in image size large enough to be demonstrable.

A photographic effect of such a displacement of images is the color fringing which could result at edges between light and dark areas. A color print at 16× enlargement of this millimeter-wide line showed quite obvious red fringes at the edge of the line. When the hardening differential is reduced by using a hardening stop and fixing bath, a smaller colored edge exists. Whether or not such a color fringe would be visible and objectionable depends on the magnification at which the image is viewed.

In certain photographic processes, the edge effects caused by physical distortion of film can produce objectionable results. These are evident as halos or light fringes which surround many dark objects. A good illustration of these effects is provided by the system in which Eastman Color Intermediate Film, Type 5253, is used to make duplicate negatives from Eastman Color Negative Film, Type 5248. Pictures photographed on the color negative are printed onto the intermediate film in order to make a color master positive. The color master positive is again printed onto the intermediate film in order to make a duplicate of the original color negative. This system provides a relatively simple method of supplying the duplicate negatives so necessary in professional motion-picture productions. When the original color negative and both intermediate film stages go through processes having acid dichromate bleach baths, distortion due to tanning can occur at each processing stage. The resulting edge effects are additive; therefore, the duplicate color negative has much greater edge effects than the original color negative. An example of the undesirable edge effects which can be obtained in this way is illustrated in Fig. 8A, where it is particularly noticeable at the boundary of

Fig. 8A. An undesirable edge effect or halo at the boundary of the model's elbow and the gray wall.

Fig. 8B. Reduction of the edge effect by use of a non-tanning bleach in the process.

the dark sweater on the model's elbow against the gray wall. If a non-tanning, bromide – ferricyanide formula is used in processing the two intermediate stages, a reduction in edge effects is obtained, as illustrated in Fig. 8B.

It should be remarked that, although in most of this discussion the edge effect has been presented as a distortion with undesirable implications, that is, color fringes or objectionable halos, there can exist conditions under which such effects enhance apparent picture sharpness. In these cases where the visible increase of edge gradient is desired, process changes which increase the hardness differential between image and non-image areas may be possible.

To summarize briefly, we have described an edge effect which is not a function of a development differential, but rather is due to physical distortions of processed film which result from a hardness differential across an exposure edge when a tanning bleach is used in a color process.

Bibliography

1. Valenkov, N., *Z. wiss. Phot.*, *27:* 236 (1930).
2. Wolfe, R. W., and Barrows, R. S., *PSA Jour.*, *13:* 554 (1947).
3. Ross, F. E., *The Physics of the Developed Photographic Image*, Monograph No. 5 on the Theory of Photography, Eastman Kodak Company, Rochester, N.Y., 1924, p. 157.

PHOTOGRAPHIC SCIENCE AND ENGINEERING
Volume 3, Number 5, September-October 1959

Comparison of the Kinetics of Development of Silver Chloride and Silver Bromide Emulsions

T. H. JAMES, *Research Laboratories, Eastman Kodak Company, Rochester, N.Y.*

A comparison was made of the kinetics of development of silver chloride and silver bromide emulsions. In the absence of sulfite, the dependence of the rate of development on the Metol concentration and on the pH is substantially the same for the two halides, although the silver chloride grains develop faster. Silver chloride, silver bromide, and silver iodide give filamentary silver on development in low-solvent developers. The activation energy of development of the chloride beyond the induction period is lower than that of the bromide. Sulfite is more effective in increasing the rate of solution of silver chloride than of silver bromide, and a transition to a solution physical mechanism occurs in the development of the chloride as the sulfite concentration increases. The activation energies of solution are substantially the same for silver chloride and silver bromide. The results are discussed in relation to the mechanism of development.

The kinetics of development of silver bromide and iodobromide emulsions by various developing agents have been studied rather extensively, but little information is available for silver chloride emulsions which are substantially free of bromide. A study of the development of silver chloride emulsions is of interest in at least two connections.

The ionic conductivity of silver chloride is lower than that of silver bromide, and the activation energy of formation of interstitial silver ions is higher in the chloride.[1] It would be expected, therefore, that development by a mechanism which involved a movement of silver ions through the halide crystal would occur at a lower rate in the development of silver chloride grains than in that of silver bromide grains. Experiments by Klein and Matejec,[1] carried out on thin sheets of silver bromide and silver chloride, gave evidence for the participation of a process which involved the movement of silver ions through the silver bromide sheet, but showed no evidence of a similar process in the silver chloride. In these experiments, a drop of developer was placed on the top surface of a sheet of silver halide which had been sensitized, exposed to light, and then floated on water. A developed zone formed where the sheet was wet with developer. Etching occurred at the under surface (in contact with the water) immediately below the developed zone on the silver bromide sheet, but not on the silver chloride. It is of interest in this connection to determine whether the mechanism of development of photographic grains of silver bromide and silver chloride is the same or different.

Communication No. 2030 from the Kodak Research Laboratories. Received 19 June 1959.

The solubility of silver chloride in water or in sulfite solution is considerably greater than that of silver bromide, and this should favor, relatively, solution physical development of the silver chloride. It is known that a high-sulfite developer which contains no bromide, such as Kodak Developer D-76, acts upon silver chloride almost entirely by the solution physical mechanism.[2,3] As Klein has shown,[3] filamentary silver indicative of direct chemical development can be obtained from silver chloride by the use of a developer of very low sulfite content, but solution physical development apparently becomes dominant at a moderate sulfite concentration for silver chloride, although not for silver bromide. Since the rate of solution physical development is dependent primarily on the rate of solution, rather than on the equilibrium solubility, quantitative data on the relative rates of solution of silver chloride and bromide in the presence of sulfite are desirable.

In the present investigation, the kinetics of development of silver chloride emulsions are compared with those of silver bromide and iodobromide emulsions of comparable grain size. N-methyl-*p*-aminophenol, in the form of its sulfate, Metol, was used as developing agent, and the comparison was made over the same range of concentrations, pH, and temperature. The results of the study indicate that silver chloride and silver bromide develop by the same mechanism in the absence of sulfite or similar solvent, and that silver chloride develops substantially faster than the bromide. On the other hand, sulfite increases the rate of solution of silver chloride to a relatively much greater extent and a transition from direct to solution physical development occurs much more readily for the silver chloride.

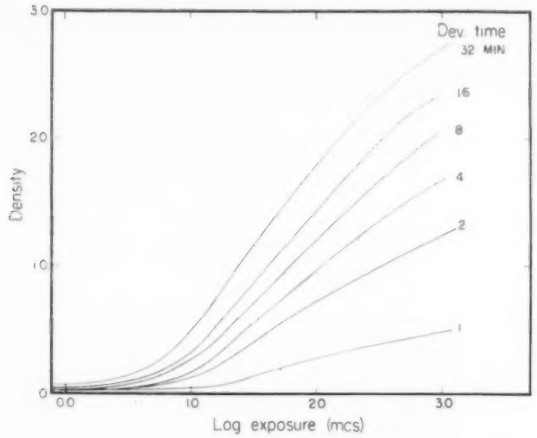


Fig. 1. Characteristic curves for development of a medium-grain silver chloride emulsion in the Metol–ascorbic acid developer at pH 6.5 and 20°C.

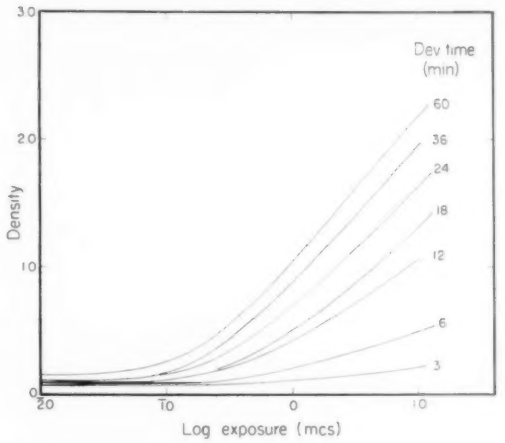


Fig. 2. Characteristic curves for development of a medium-grain silver bromide emulsion in the Metol–ascorbic acid developer at pH 6.5 and 20°C.

Experimental Materials and Procedure

Fine- and medium-grain silver chloride and silver bromide experimental emulsions, a fine-grain silver iodide emulsion, and a fine-grain motion-picture-positive iodobromide emulsion were used. The silver chloride emulsions were prepared without addition of any bromide. The chloride emulsions showed a lower sensitivity to white light than the bromide emulsions of corresponding grain size, but gave characteristic curves of roughly similar form when processed in a low-solvent Metol–ascorbic acid developer of the following composition:

Metol	7.0 grams
D-Araboascorbic acid	5.0 grams
Potassium chloride	0.4 gram
0.5 *M* Disodium phosphate	180.0 ml
Water to make	1000.0 ml

pH at 20.0°C, 6.5

Figures 1 and 2 show development time series for the characteristic curves of medium-grain silver chloride and medium-grain silver bromide emulsions.

Development was carried out in a nitrogen atmosphere in solutions which had been deaerated with nitrogen, and nitrogen-burst agitation was used. The temperature was 20.0°C, unless otherwise specified. Two types of exposure were used. In one, the film strips were exposed on the Eastman IIb Sensitometer (time-scale) with the standard positive lamp and filter. In the other, uniform exposures were made to a 6-w tungsten lamp operated at 115 v at a distance of 140 cm from the film and shielded by a ground-glass plate. The exposure was for 15 min to the emulsion side of the film, followed by 15 min to the base side. This exposure was sufficient to make substantially all grains of the silver bromide and iodobromide emulsions developable and corresponded to the upper portion of the straight-line part of the characteristic curve for the silver chloride materials. In some tests, the silver chloride coatings were exposed to a 40-w lamp under the conditions just described.

The rates of solution of the silver halides were determined on special coatings of the same emulsion grains with colloidal silver incorporated in the coating, as described in an earlier paper.[4]

The developed densities of strips which had been exposed on the IIb Sensitometer were read on an automatic densitometer with white light. Spectrophotometric density traces were obtained in the uniformly exposed strips, and densities could be read at any particular wavelength. Silver determinations were made on a fluorescent x-ray spectrometer.

Results

Latent-Image Development

The silver formed by development of silver chloride grains in a low-pH Metol developer, with ascorbic acid added to remove oxidation products of the Metol,[5] is filamentary, and resembles that obtained by development of silver bromide and silver iodide in low-solvent developers. Figure 3 shows electron micrographs of silver obtained (A) from silver chloride developed by a Metol–L-ascorbic acid–potassium chloride developer of pH 6.4; (B) from silver bromide developed by a Metol–L-ascorbic acid–potassium bromide developer of pH 9.6, both at 20°C; and (C) from silver iodide developed by a pyrogallol–low-sulfite developer of pH 10.6 used at 50°C. The three developers acted at roughly equal rates on the respective halides. The filaments obtained from the silver chloride appear to be somewhat finer and more tightly packed than those from the silver bromide and iodide, but otherwise the form of the silver obtained from the three halides is similar.

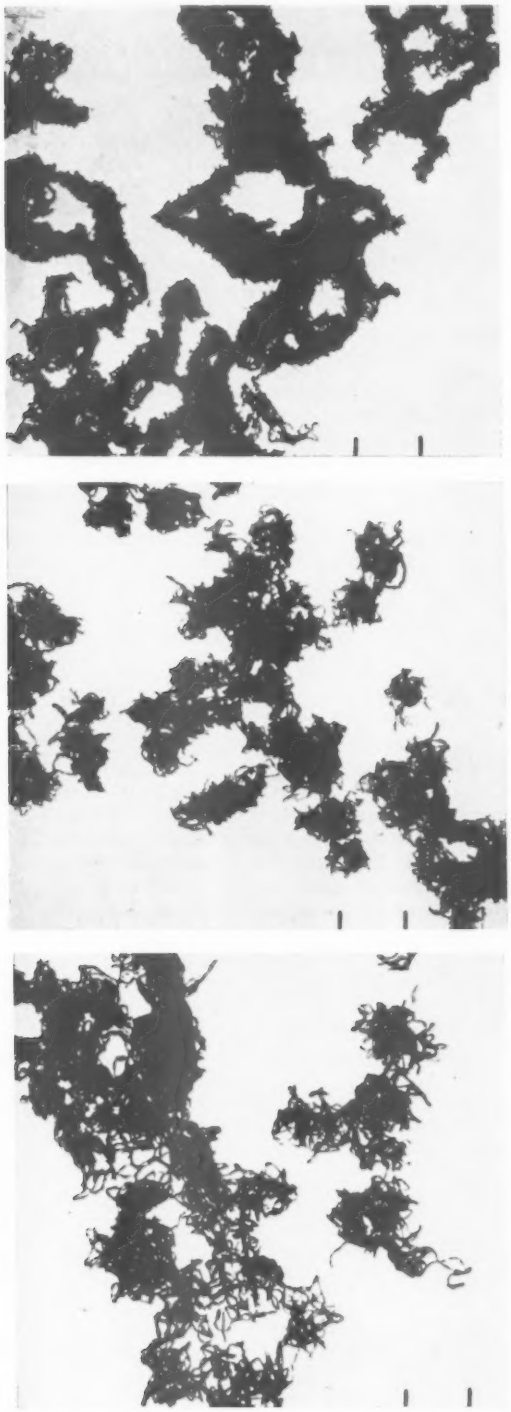


Fig. 3. Silver formed by development of: *top*, silver chloride; *middle*, silver bromide; and *bottom*, silver iodide in low-solvent developers. Parallel lines represent 1 μ.

Both the silver chloride and the silver bromide emulsions develop in the Metol–ascorbic acid developer with a short but definite induction period. Earlier work had shown[6] that the induction period was substantially independent of grain size in a simple silver bromide emulsion series where a sulfite-free hydroquinone was used as developer. In the present investigation, the induction period for the Metol developer likewise did not depend significantly on grain size for the particular halide. Figure 4 shows this for the two chloride emulsions. The developer had the same composition as that used to obtain Figs. 1 and 2. The coatings were exposed for 30 min total time to the 6-w source. The mass of silver per square decimeter is plotted against development time. A curve for the fine-grain iodobromide emulsion is included for comparison. The rate of development of both chloride emulsions beyond the induction period is considerably higher than that of the iodobromide.

The dependence of the rates of development of the fine- and medium-grain silver chloride coatings and the medium-grain bromide coating on the Metol concentration at pH 6.6 is shown in Fig. 5, where the logarithm of the rate is plotted against the logarithm of the concentration. The developing solution contained 5.0 grams l-ascorbic acid and 0.4 gram potassium chloride per liter, and the Metol concentration was varied over a 16-fold range. The exposure levels were well on the shoulders of the characteristic curves. The rates were determined as the average slopes of the density–time of development curves between densities of 0.2 and 0.6; these are substantially maximum rates for the particular development conditions. Control experiments showed that the

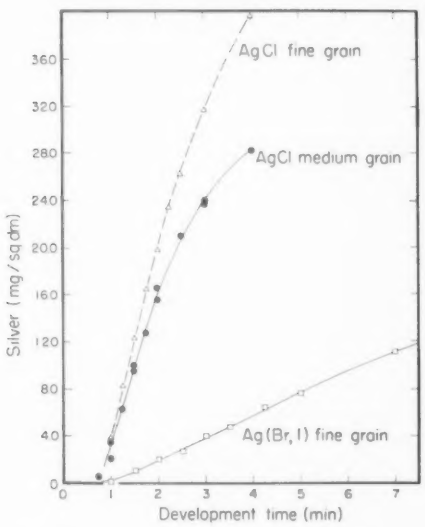


Fig. 4. Silver-development time curves for fine- and medium-grain silver chloride and fine-grain silver iodobromide emulsions in the Metol–ascorbic acid developer at pH 6.5 and 20°C. All emulsions exposed for a total of 30 min to the 6-w tungsten source.

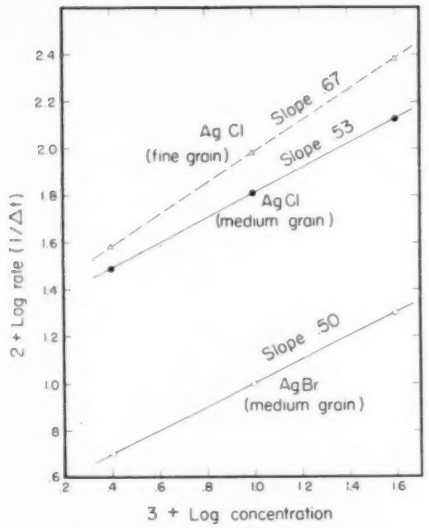


Fig. 5. Dependence of rate of development on Metol concentration; pH 6.6; 20°C.

ascorbic acid by itself acted too slowly to contribute to the over-all rate of development, which therefore represented only the Metol. The development rates varied as a fractional power of the Metol concentration for both halides, and the fractional power is nearly the same for the medium-grain chloride as for the bromide. The relation between developed silver and developed density did not change significantly with change in Metol concentration or pH, and the same relative results were obtained when the rate measurements were based on silver values.

The relative dependence of rate upon pH is the same for the chloride as for the bromide emulsions. Figure 6 shows a plot of the logarithm of the rate against pH for the medium-grain chloride and bromide emulsions. The curves are substantially parallel.

Chloride ion acts as a fog-restrainer in the development of the silver chloride emulsions, just as bromide ion does in the development of silver bromide and iodobromide emulsions. An increase in chloride-ion concentration also increases the relative induction period in the development of the chloride emulsions.

The temperature-dependence of the rate of development of the fine- and medium-grain silver chloride emulsions was determined, and compared with that of development of the motion-picture-positive, fine-grain iodobromide emulsion. The latter was chosen for the comparison because of the considerable amount of data already available on the temperature-dependence of development of that material in various solutions.[7,8] Rates determined both in terms of the developed silver mass and developed density (measured at 700 mμ) fitted the Arrhenius equation satisfactorily, and activation energies calculated for the two types of rate measurements agreed to within 1 kcal/mole in most instances, which is within the

TABLE I

Dependence of Rate of Development of Silver Chloride and Silver Iodobromide Emulsions on Temperature

Developer: Metol, 7.0 grams; L-ascorbic acid, 5.0 grams; KCl, 0.4 gram/liter
Phosphate buffer to pH 6.4. 30-min exposure to 6-w source.

Coating	Temperature degrees K	Slope rate mg Ag/ sq dm	Induction period rate $1/t$
Fine-grain chloride	275.5	4.2	0.165
	283.8	6.9	0.40
	293.0	13.8	0.96
	302.7	26.7	1.82
Medium-grain chloride	275.8	5.9	0.195
	283.7	9.1	0.435
	293.0	17.2	1.00
	302.7	26.3–30.5	2.22
Fine-grain iodobromide	283.7	0.83	0.13
	293.0	2.15	0.33
	302.7	4.5	0.74
	311.8	8.8	1.43

limits of experimental error. This agreement depends on the fact that the covering power of the silver did not change significantly with temperature. Rate data based on silver determinations are given in Table I for both slope rates and reciprocal time rates. The latter, measured in terms of the time required to reduce approximately 10% of the total available silver halide, are largely induction-period rates.

The activation energies calculated from the temperature-dependence data are listed in Table II. Included also are results obtained by development of the iodobromide emulsion in a Metol–ascorbic acid developer which contained 1 gram potassium bromide per liter at pH 8.25. The calculated activation energies for development of the fine- and medium-grain silver chloride emulsions do not differ significantly. The activation energies for the chloride and the iodobromide are about the same in the induction-period region ($1/t$ rates) but the activation energy for the

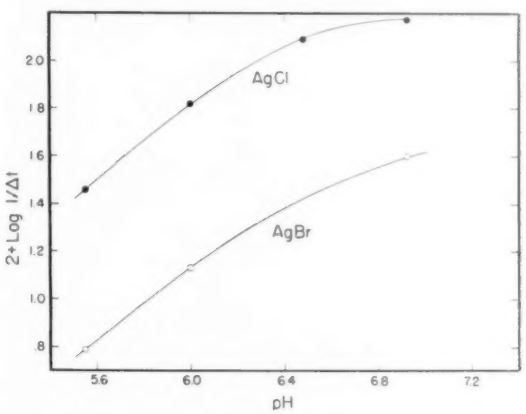


Fig. 6. Dependence of rate of development on pH at 20°C.

TABLE II

Calculated Over-all Activation Energies for Development in the Metol – Ascorbic Acid – KCl Solution of pH 6.4

Coating	Exposure	Activation energies (kcal/mole)			
		Density-base rates		Silver-base rates	
		$1/t$	Slope	$1/t$	Slope
Fine-grain chloride	6-w	15.2	11.4	16.0	11.4–11.9
	40-w	14.6	11.4		
Medium-grain chloride	6-w	15.0–15.5	10.8–11.0	14.6–15.5	10.1–10.5
Fine-grain iodobromide	6-w	15.0	14.4	15.3	14.6
	6-w			16.0*	14.5*

* Metol – ascorbic acid – KBr developer, pH 8.25.

chloride is smaller by about 4 kcal/mole than that for the iodobromide beyond the induction period. An incidental observation is that the activation energies given here for development of the iodobromide material exposed to the low-intensity light source are lower than those previously obtained[7] with a similar developer when the material was exposed to a light source of much higher intensity. The values, 16.0 and 14.5, obtained in the present work for the developer of pH 8.25 are to be compared with the values of 20.9 and 16.1 obtained in the previous work for a developer of pH 8.5.

The addition of sodium sulfite to the Metol–ascorbic acid developer alters the course of development. Table III illustrates the effect of various amounts of sulfite on the induction-period rate ($1/t$) and subsequent rate of development (R), where rates are measured in terms of mass of silver per unit area per unit time. Even a small amount of sulfite decreases the induction-period rate. The rate beyond the induction period increases slightly with the addition of 6.5 grams sodium sulfite per liter, but decreases when the larger amounts of sulfite are added. The character of the developed silver, both as shown by absorption spectra (Fig. 7) and electron micrographs, changes to that typical of solution physical development when the higher amounts of sulfite are added. Klein has made similar observations[3] on the effect of sulfite on the form of the developed silver, as shown by the electron microscope. The effect of the sulfite on the rate of development is similar to that observed in previous work on the development of silver bromide grains by *p*-phenylenediamine[9] in neutral and moderately alkaline solution, and by hydroxylamine.[10] In each case, the transition in the mechanism from direct chemical to solution physical development was accompanied by a decrease in net rate of development.

TABLE III

Effect of Sulfite on Rate of Development of Medium-Grain Silver Chloride

Metol – ascorbic acid developer with 0.4 gram KCl; pH 7.15; 20.0°C. 30-min exposure to 6-w source.

Sodium sulfite grams/liter	Induction-period rate, $1/t$	Slope rate mg Ag/sq dm/min
0	2.08	27.5
6.5	1.59	30.1
32.5	0.85	25.3
50.0	0.80	20.4

Rate of Solution and Solution Physical Development of Silver Chloride Grains

The rate of solution of pure silver chloride in the presence of excess chloride ion decreases to a minimum and then increases as the chloride-ion concentration increases. The curve representing rate as a function of chloride-ion concentration is similar in form to that representing the rate of solution of silver bromide as a function of excess bromide-ion concentration. Comparative data and photomicrographs of the silver chloride and bromide grains have been published elsewhere.[11]

The effect of temperature on the rate of solution of the silver chloride in the presence of various amounts of potassium chloride is shown in Table IV. The data fit the Arrhenius equation satisfactorily, and activation energies can be calculated in the usual way. These values are listed in Table IV.

TABLE IV

Dependence of Rate of Solution of Silver Chloride Grains on Temperature

Developer: Metol, 7.0 grams; L-ascorbic acid, 5.0 grams; 0.5 *M* Na_3PO_4, 60 cc; total volume, 1 liter; pH 6.5

Coating	Temperature degrees K	KCl grams/liter	Slope rates mg Ag/sq dm/min	Rate $1/t$ (Ag = 1.0)	Activation energy	
					Slope rates	$1/t$ rates
Fine-grain	276.3	None	0.134	0.17		
	283.8	None	0.30–0.32	0.47		
	293.0	None	0.88	1.16		
	303.0	None	2.46	2.70	18.0	18.4
Fine-grain	276.2	1.0	0.072–0.077	0.085		
	276.4	1.0	0.075	0.091		
	283.9	1.0	0.184	0.24		
	293.0	1.0	0.57	0.66		
	303.0	1.0	1.64	1.89	19.1	19.1
Medium-grain	276.4	5.0	0.040	0.074		
	283.7	5.0	0.102	0.17		
	293.0	5.0	0.29	0.45		
	303.0	5.0	0.87	1.27	18.7–19.1	17.8

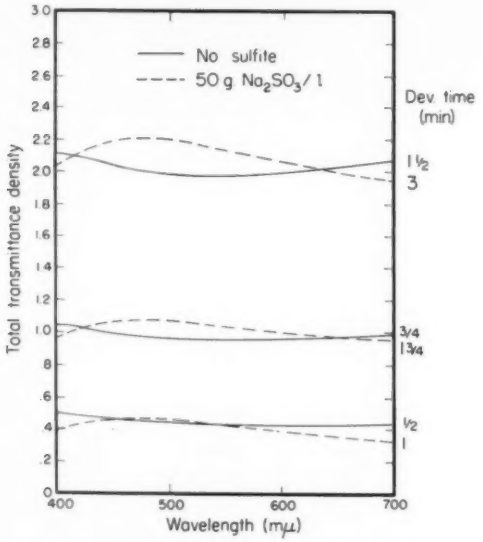


Fig. 7. Spectrophotometric curves for silver obtained by development of medium-grain silver chloride by Metol in the absence of sulfite (solid curves) and in the presence of 50 grams sodium sulfite per liter (broken curves); pH 7.15; 20°C.

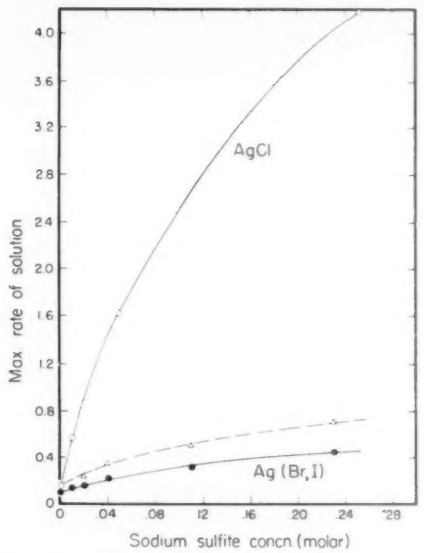


Fig. 8. Effect of sulfite on the rate of solution of medium-grain silver chloride and fine-grain silver iodobromide at 20°C. The broken curve represents the curve for the silver iodobromide normalized to give the same rate as the silver chloride in the absence of sulfite.

Sodium sulfite has a marked effect upon the rate of solution physical development of silver chloride. This is illustrated in Fig. 8, where slope rates (as mg silver/sq dm/min) are plotted against the sulfite concentration at pH 7.15. A similar plot is given for the rate of solution of grains of a motion-picture-positive silver iodobromide emulsion. The relative differences between the rates for the chloride and iodobromide grains can be seen from a comparison of the curve for the chloride with the broken curve. The latter represents the data for the iodobromide grains "normalized" to give the same rate as the chloride in the absence of sulfite (i.e., all rates were multiplied by a constant factor).

Discussion

The results of the present study of the kinetics of development of silver chloride grains in the absence of sulfite indicate that the mechanism of development is the same as that for silver bromide and silver iodobromide grains. The silver chloride and bromide emulsions show the same relative dependence of rate of development on the concentration of the developer and on the pH of the solution. For both the chloride and bromide, the rate of development varies as a fractional power of the Metol concentration. The fraction differs somewhat from emulsion to emulsion, but that is not unexpected if the basis for the fractional-power variation is adsorption of the developing agent. Some differences in adsorption are to be expected.

The relative increase in rate of development with increase in the pH of the solution drops off at the higher pH levels used in the present work. The data are not sufficiently detailed for quantitative analysis in terms of the relative activities of the possible developer species. The initial rapid rise in rate with increase in pH in the low-pH region probably is largely due to the dissociation of the $-\overset{+}{N}H_2(CH_3)$ group to $-NH(CH_3)$ and $\overset{+}{H}$. The pK value for this dissociation is in the neighborhood of 6. Cameron's data[12] indicate a value of about 5.75 at 20.0°C, and Fieser[13] gives the value as 5.9 at 25°C. The free base probably is active as a developer. The singly charged negative ion has a much higher specific activity than the free base, but is present in relatively low concentrations in the pH range studied. Probably both the free base and the negative ion play a part in the development of both the chloride and bromide grains in this pH region.

The activation energy of initiation of development of the silver chloride grains (as deduced from the $1/t$ rates) is about the same as for the silver iodobromide grains. The activation energy of development beyond the induction-period region for the high-level, low-intensity exposures used in this study is several kilocalories per mole less for the chloride than the corresponding value for the iodobromide grains. This latter result is in agreement with results previously reported by Sheberstov and Donatova[14] for a different developer. The lower activation energy is consistent with the higher specific rate of development of the silver chloride. The lower activation energy and higher rate of development of the silver chloride,

however, does not appear to be consistent with a mechanism of development based on movement of silver ions within the crystal.

The general form of the developed silver is the same for silver chloride, silver bromide, and silver iodide when fairly rapid development by low-solvent developers is used. The silver has a pronouncedly filamentary structure. Development of silver chloride grains, however, is relatively more sensitive to solvent effects than development of silver bromide or iodide, and a complete shift to a solution physical development mechanism takes place under conditions of relatively mild solvent action when pure silver chloride emulsions are used. Thus, development of the silver chloride emulsions in the solution containing 50 grams sodium sulfite per liter takes place largely by the solution physical mechanism, whereas chemical development dominates in the action of the same developer on silver bromide and iodobromide grains.

The relatively much greater effect of sulfite on the mechanism of development of silver chloride grains can be explained on the basis of the relative rates of solution. As shown in Fig. 8, the rate of solution of the medium-grain silver chloride in the absence of sulfite is only slightly greater than that of the fine-grain silver iodobromide. With the addition of sodium sulfite, however, the relative rate of solution of the silver chloride increases much faster than that of the iodobromide. The rate of solution physical development for the conditions used is much more dependent on the rate of solution of the silver halide than on the specific rate of reduction of silver ions at the developing centers. Hence, much smaller amounts of sulfite should be needed to shift the mechanism of development to the solution physical type for a silver chloride than for a silver bromide or iodobromide material.

The activation energy of solution of silver chloride in the Metol–ascorbic acid developer either in the presence or absence of added chloride ion does not differ significantly from that of silver bromide in the absence of excess bromide ions or in the presence of a small excess. The values previously obtained[4] for silver bromide are 18.2 kcal/mole in the absence of added bromide ion and 20.1 in the presence of 1 gram potassium bromide per liter. The average values obtained in the present work on silver chloride are 18.2 in the absence of excess chloride ion and 19.1 in the presence of 1 gram potassium chloride per liter. Previous work had shown that the shape of the curves representing the rate of solution of silver chloride as a function of excess chloride ion and of silver bromide as a function of excess bromide ion are quite similar.

References

1. Cf. Klein, E., and Matejec, R., *Z. Elektrochem., 61:* 1127 (1957); Mitchell, J. W., *Reports on Progress in Physics, 20:* 433 (1957).
2. James, T. H., *Phot. Sci. and Eng., 1:* 141 (1958).
3. Klein, E., *Z. Elektrochem., 62:* 505 (1958).
4. James, T. H., and Vanselow, W., *Phot. Sci. and Tech., 2:* 135 (1955).
5. James, T. H., *PSA Jour., Sect. B (Phot. Sci. and Tech.), 19B:* 156 (1953).
6. ———, *J. Franklin Inst., 243:* 235 (1947).
7. ———, *Phot. Sci. and Tech., 2:* 81 (1955).
8. Fortmiller, L. J., Exley, N. A., Ives, C. E., and James, T. H., *Phot. Eng., 7:* 171 (1956).
9. James, T. H., *J. Phot. Sci., 6:* 49 (1958).
10. ———, *J. Phys. Chem., 47:* 597 (1943).
11. ———, and Vanselow, W., *J. Phys. Chem., 62:* 1189 (1958).
12. Cameron, A. E., *J. Phys. Chem., 42:* 1217 (1938).
13. Fieser, L. F., *J. Am. Chem. Soc., 52:* 4915 (1930).
14. Sheberstov, V. I., and Donatova, V. P., *Zhur. Nauch. i Priklad. Fotografii i Kinematografii, 2:* 277 (1957).

PHOTOGRAPHIC SCIENCE AND ENGINEERING
Volume 3, Number 5, September-October 1959

Adsorption and Structure of Sensitizing Dyes

E. KLEIN AND F. MOLL, *Agfa Research Laboratories, Agfa AG, Leverkusen, Germany*

The adsorption of 12 symmetrical cyanine dyes to silver halide in a 1.2% gelatin solution was determined. The dyes differ in the type of heterocyclic nuclei, as well as in the number of connecting methine groups. It is indicated that a relation exists between the basicity of the dyes ($N^{III} \rightarrow N^{IV}$, determined by light absorption) and the adsorption to silver bromide (determined by the maximum coverage of the grain surface). In a comparison of the dyes with an equal number of methine groups, the adsorption increases with the basicity of the ring. In the same manner, the adsorption is intensified when, with identical ring structure, the number of methine groups is increased. Each adsorption isotherm passes over into a range of saturation which, for the highly basic dyes, corresponds to a monomolecular covering of the silver bromide (if "edge on" adsorption occurs). Dyes with more limited basicity cover between 3 and 80% of the surface, which indicates the existence of ranges of different "activity" on the grain surface.

A necessary condition for the application of organic dyes as optical sensitizers for photographic purposes is the adsorbability to the silver halide grain. In addition to the always present dispersion forces, the factors responsible for adsorption include Coulomb forces in the case of basic and acid dyes, and ion-dipole forces in the case of highly polar merocyanines.

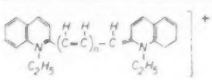
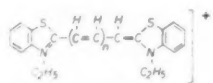
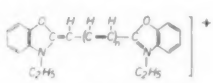
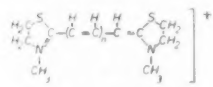
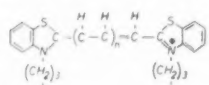
The symmetric cyanine dyes examined in this paper are single positively charged cations. In the interaction between dye and silver halide, however, considerable differences are apparent as a result of the constitution of the dye. Normally, the heat of adsorption is employed for the determination of the interaction between adsorbent and adsorbate. The enthalpy of adsorption of different sensitizer dyes on silver halide in the presence of gelatin has been measured by West, Carroll, and Whitcomb,[1] whereby values between 4 and 13 kcal/mol of sensitizer dye have been established. These values, however, fail to correspond to the pure adsorption heats, since part of the energy is used to partly or entirely displace the gelatin from the silver halide surface.[2,3] By determining the adsorption isotherms it is possible to estimate the equilibrium between gelatin, dye, and silver halide surface, and to state the intensity of the adsorption of the dyes. In the present investigation, the constitution of the dyes was systematically altered, and attempts were made to find a relation between the structure and adsorption intensity.

Experimental Procedure

The adsorption isotherms were determined by the method described by West, Carroll, and Whitcomb[1]: An exactly known quantity of dye solution was added to the emulsion and stirred for two hours in a thermostat at 40° C in order to attain the equilibrium. The emulsion was then centrifuged at 40° C, and the supernatant solution measured photometrically. The spectra were measured with an automatically recording Carry-spectrophotometer. The emulsion contained pure AgBr grains, the content of gelatin was 1.2%, while pH was 6.5 and pAg was 7.8. The mean grain surface was determined very accurately from electron-microscopic stereophotographs and was found to be 2.27 sq m/gram AgBr.

The dyes shown in Table I were examined*:

TABLE I

Constitution	Designation	λ_{max} (in water) ($c = 10^{-5}$ mol/liter)
	I_0: n = 0 I_1: n = 1	523 mμ 600 mμ 548 mμ
	II_0: n = 0 II_1: n = 1	422 mμ 555 mμ
	III_0: n = 0 III_1: n = 1 III_2: n = 2	372 mμ 478 mμ 575 mμ
	IV_0: n = 0 IV_1: n = 1 IV_2: n = 2	332 mμ 442 mμ 537 mμ
	V_0: n = 0 V_1: n = 1	425 mμ 558 mμ

Received 17 June 1959. To be presented at the National Conference, Chicago, Ill., 29 October 1959.

* We are indebted to Drs. J. Götze and O. Riester of these Laboratories for the preparation of highly purified dyes.

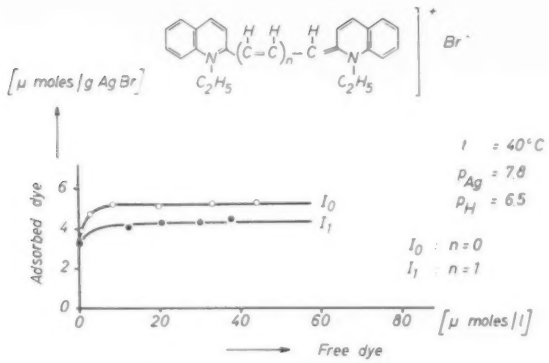


Fig. 1. Adsorption isotherms of Dyes I.

Results and Discussion

Adsorption isotherms of 1,1′-diethyl-2,2′-cyanine and the corresponding carbocyanine are shown in Fig. 1. The isotherm of I_0 rises steeply and attains saturation at $5.1 \cdot 10^{-6}$ mol of adsorbed dye per gram AgBr. This corresponds to a space of 74 A^2 required per dye molecule. The value is in accordance with values measured by other authors[1,7] and corresponds to an adsorption of the molecules "edge on" to the silver halide in the case of a monomolecular layer. The corresponding carbocyanine requires somewhat more space, and therefore attains saturation concentration when $4.3 \cdot 10^{-6}$ mol dye per gram AgBr are adsorbed.

In the case of symmetric benzothiazoles, a complete covering also occurs, although only at higher concentrations of free dye in solution (Fig. 2).

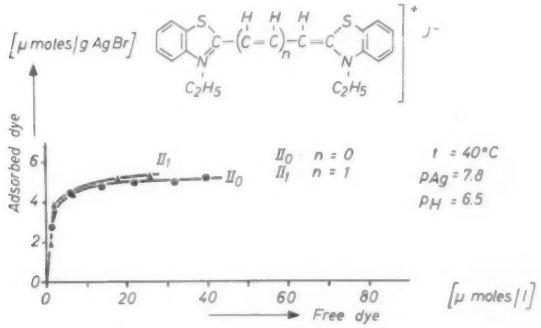


Fig. 2. Adsorption isotherms of Dyes II.

This, however, can only mean that these dyes are less able to displace the gelatin than dyes I. The influence of structure on the adsorption of the dye is even more pronounced in the case of benzoxazoles (Fig. 3). While dye III_2 shows a complete covering of the grain surface, dye III_1 covers only 80%, and

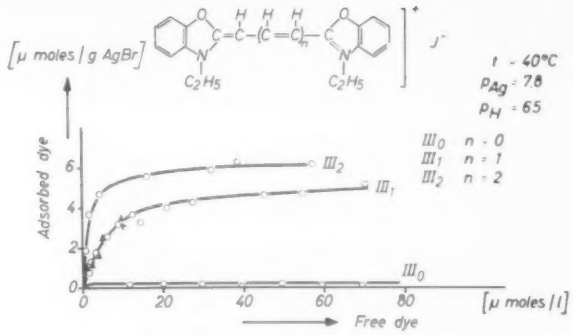


Fig. 3. Adsorption isotherms of Dyes III.

III_0 merely about 3%. Dye IV (Fig. 4) fails to offer a complete covering at any concentration. In the case of IV_2 40% of the grain surface is covered, with IV_1 11%, and with IV_0 only 3%. (In each case the calculation was made assuming an "edge on" adsorption of the molecule. It is not possible to attain a complete covering with a "flat on" adsorption of the dye molecules either.)

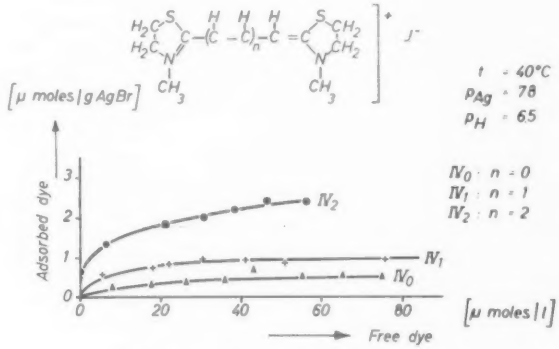


Fig. 4. Adsorption isotherms of Dyes IV.

All dyes indicate in their isotherms a saturation concentration for the adsorption, i.e. even a large increase in the concentration of the free dye in solution fails to cause any further adsorption. Some dyes are able to cover the grain completely, while other types can only cover a fraction of the grain surface. This leads to the conclusion that the grain surface is heterogeneous, and that dyes exerting only a limited interaction with the silver halide can only occupy places of highest "activity." A few papers recently published also indicate a heterogeneity of the surface.[1,4] The type of the disturbing factors cannot be established definitely. The opinion has been expressed[5] that different crystal faces are responsible for the nonuniform adsorption. Although electron-micrographs indicate only (111) faces, it is possible that a microstructure consisting of (100) faces exists, whereby it is not necessary that all the

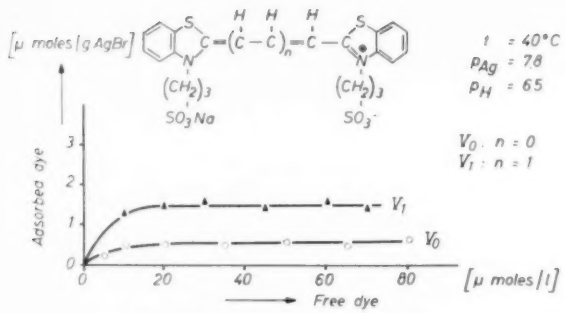


Fig. 5. Adsorption isotherms of Dyes V.

(100) faces are energetically equivalent in the adsorption.

How can the behavior of the individual dyes be explained? A comparison of the adsorption spectra and adsorption isotherms of dyes with an identical number of methine groups indicates that—*cum grano salis*—a relationship exists between absorption and adsorption, i.e. that dyes absorbing at longer wavelengths generally adsorb far better. The absorption of these dyes, in turn, can be fully understood with the aid of Brooker's basicity law.[6] Dyes with nuclei which are more intensively basic absorb at longer wavelengths than dyes with less basic nuclei. (The term "basicity" is used here in the sense of a stabilization of the transition $N^{III} \rightarrow N^{IV}$.) The more basic the nitrogen, the larger is the share of Coulomb forces in the interaction with the negative halide ion of the crystal lattice. A lengthening of the methine chain causes an increase in the number of π electrons, and thus an increase of dispersion forces, which in turn causes an intensification of the adsorption forces. It is, of course, not possible to generalize the relation between adsorption and absorption. It is only valid in so far as the absorption data permit comparisons of the basicity of similar dyes. Thus, the state of charge of the N-atoms appears to be of decisive influence, as mentioned already by Sheppard et al.[7] When the charge of the N-atom within the dye molecule is neutralized by corresponding substitution under formation of a betaine, adsorption drops markedly (Fig. 5).

The decrease of adsorption need not be attributed only to the neutralization of the charge. It is also possible to increase the distance between halide ion and dye by large substituents, and thus to impair the interaction.

As mentioned already by several authors, a connection between adsorbability and sensitizing cannot be directly established, since the energy transfer from dye to silver halide takes place in an excited state of the dye, while very little is actually known about the conditions of adsorption in an excited state.

Acknowledgment

We express our sincere appreciation to Dr. J. Götze and Dr. O. Riester for placing the dyes at our disposal, as well as to Dr. Matejec for numerous elucidating discussions.

References

1. West, W., Carroll, B. H., and Whitcomb, D. L., *J. Phys. Chem.*, *56:* 1054 (1952).
2. ———, *J. Phot. Sci.*, *1:* 145 (1953).
3. James, T. H., and Vanselow, W., *J. Am. Chem. Soc.*, *73:* 5617 (1951).
4. Petruschkina, S. L., *Zhur. Nauch. i Priklad. Fot. i Kinematog.*, *2:* 15 (1957).
5. Schwab, G. M., private communication.
6. Brooker, L. G. S., White, F. L., and Sprague, R. H., *J. Am. Chem. Soc.*, *73:* 1087 (1951).
7. Sheppard, S. E., Lambert, R. H., and Walker, R. D., *J. Chem. Phys.*, *7:* 265 (1939).

PHOTOGRAPHIC SCIENCE AND ENGINEERING
Volume 3, Number 5, September-October 1959

• Book and Journal Reviews

How Photography Works

H. J. Walls, The Macmillan Co., New York, 1959, 351 pp., 5 1/2 by 8 1/2 in., $8.50.

Dr. Walls, who is Director of the Forensic Science Laboratory in Newcastle, has written with clarity and a touch of humor an introductory account of the theory of the photographic process. According to the preface, the book "assumes no scientific knowledge whatever" and an attempt is made to supply the basic information needed in chemistry and physics by the inclusion of chapters and sections on these subjects interspersed with the material on photographic theory. Extensive use is made of analogy and of illustrative drawings in the explanation of points of theory.

Latent image formation and development are presented in terms of Mitchell's more recent theorizing, and the reader is introduced to such concepts as the "positive hole" and the "kink site." The presentation is clear in most instances. An exception is the discussion of solarization which, for clarity, needs more explanation than is given. Readable accounts of after-processing, sensitometry, image structure, tone reproduction, and color photography follow the material on exposure theory and development.

I am not always in agreement with the author in his choice of explanations for the various phenomena discussed, but I realize that alternative theories cannot always be included in a book of this kind. The book contains a few statements which are either erroneous or are likely to be given an erroneous interpretation, such as the statement on p. 162 that "amino developing agents are used in nearly neutral solution," and the one on p. 83 that "the silver bromide grains in the emulsion . . . . . are mostly hexagonal or triangular plates 1/1000 to 4/1000 mm across." Neither statement is true in the general sense indicated. Typographical errors are few — remarkably so for a first edition. A good selection of book and journal references is given at the end of each chapter for the reader who may wish to pursue the subject further. This book can be recommended to the non-specialist as an interesting and instructive presentation of basic theory.— *T. H. James*

Lexique Anglais-Français des termes appartenant aux techniques en usage à l'Institut Géographique National

First Part (2 vol.), 451 pp., paper cover, 8 1/4 × 10 1/2 in.; Second Part, 122 pp. (1959).

The lexicon, prepared initially for the personnel of the Institut Géographique National, covers terms used in geodesy, topography, cartography, optics, general photography, and reproduction processes, together with some terms relative to chemistry and physics. It is more than an English-French language dictionary in that, in addition to supplying the French equivalents of English words and terms, it often supplies definitions (in French) as well. It also includes trilingual (English, French, German) sections on magnitudes and units; tables of sizes of cards, photographic papers, plates, and films; conversion tables of photometric units, weights and measures, and temperature. The lexicon is available for 3000 francs for the three volumes from Service des Cessions de Cartes, 107, Rue la Boétie, Paris VIII.

Photographic Chemistry

Pierre Glafkidès, Vol. 1, Tr. from 2nd French ed. (1957) by Keith M. Hornsby, Fountain Press, London, 1958; distributed by Macmillan, New York, 1959. 491 + xiii pp., 6 × 9 3/4 in., $21.00.

This volume is a translation of somewhat more than half of Glafkidès's book on photographic chemistry. It covers the material on the formation and development of the latent image, developer analysis, fixation and special processing, sensitometry, and the preparation of photographic emulsion. Volume 2, to be published later, will deal with color photography and will include optical sensitization.

Mr. Hornsby has presented a translation which should be of great value to those who seek a generalized technical perspective of the photographic process. However, it is not a book which can be recommended to the unsupervised serious student who is primarily interested in learning photographic theory. Its usefulness as a textbook is seriously impaired by frequent errors and by the vague and uncritical manner in which some important subjects are treated. The fault lies in part with the translator, whose mistakes in translation and poor choice of words have changed or obscured the meaning of some passages. Two sentences on page 25 may be quoted as the products of bad translation: "The study of the effects of conductivity reveals that an abrupt increase in the specific heat of the crystal of AgBr conduces to the formation of these defects," and "Berg even accepts the existence of shallow secondary traps which act as an intermediate image, the electrons captured by these traps being reduced by thermal agitation and the silver ions dispersed." I shall not comment in detail on the remainder of this section on "defects of the crystal lattice," other than to suggest that it will cause more confusion than clarification in the reader's mind.

All too often, statements are made without qualification which may be true under certain conditions but which cannot be accepted as generalizations. Among these are: "diaminophenol acts mainly at the bottom of the emulsion layer;" "the apparent sensitivity of an exposed emulsion is doubled if the temperature [of

the developer] is increased, for example, from 15°C to 33°C;" and "soluble bromide has no influence on developers with zero charge." Among the questionable or meaningless "explanations" is the explanation of why "*p*-phenylenediamine is at the same time a developer and a solvent": "this property is attributable to its oxidation products." The explanation of why the reciprocity law holds for direct x-ray exposure reads: "because of the independence of these radiations towards the centres of attraction of the sensitive crystals."

On the credit side, many chapters contain extensive literature references which will guide the reader to original sources. Useful information is given on the chemical properties of many developing agents, on the analysis of developers, and on special processing procedures. A good selection of developer and fixing-bath formulas is included. The section on photographic emulsions and the raw materials used in their preparation is extensive and occupies 213 pages (Chapters XVII to XXV). Numerous emulsion formulas are given, including those of some German emulsions obtained by F.I.A.T. reports. The discussion of emulsion addenda is detailed, with many references to the journal and patent literature. (Some errors were noted in the references, however, and a reference such as the one on page 379 to "Bulow and Mitarbeiter's method" suggests that original sources were not always checked.) Even these portions of the translation could have been improved by more careful proofreading and judicious editing. — *William S. Shoemaker, Rochester Institute of Technology*

Observations on the Destruction of the Latent Image of Desensitized Photographic Materials by White Light

A. Libicky, *Českosl. Časop. Fys., 8:* 89–92 (1958) (in Czech)

A study was made of the action of a supplementary exposure by white or spectrally selected light on undeveloped silver chloride and silver chlorobromide emulsions, exposed to the white light through a sensitometric wedge and then desensitized by dyes (pinakryptol green, pinakryptol yellow and phenosafranine with different conditions of bathing concentrations and times). It was found that the supplementary exposure by white light could bring about a decrease or increase in the density of all or part of the sensitometric strip, depending on the ratio of the main and supplementary exposures. Their limiting ratio, separating the region of intensifying action of the supplementary exposure from the region where the supplementary exposure destroys the latent image, changes somewhat as the conditions of bathing change. In spectrally selected light, a small supplementary exposure destroys the latent image regardless of what part of the spectrum is chosen; two maxima of desensitization are then observed — one in the region of natural sensitivity of the silver halide, and the other in the region of absorption of the dye (as in the Herschel effect). The position of the second maximum depends on the level of the supplementary exposure. This all indicates that the intermediate desensitization does not affect the main action of the supplementary exposure, which consists of the simultaneous destruction of latent image already formed and the formation of new latent image. — *S.C.G.* (*Translated from* Referativnyĭ Zhur., Fizika, *291*, *No. 1*, *1959*)

A Study of the Change of the Structure-Mechanical Properties of Photographic Emulsions During Drying

L. A. Lepilkina, *Kolloid. Zhur., 19:* 678–683 (1957); English translation, *Colloid Jour., 19:* 677–682 (Complete journal translation by Consultants Bureau, Inc., New York, N.Y.)

For three types of photographic emulsions (lantern-slide, positive and "ultrarapid") a study was made of the curves of kinetic deformation at constant load, and of the relation between the tangential stress and the relative strain with a given loading regime during drying, with different values of humidity and temperature. It was found that the stresses arising in the emulsion during drying lead to the formation of a new structure which may be observed with the aid of the electron microscope. This change is accompanied by the transition of the emulsion from the visco-elastic to the elastic state with a corresponding increase in the modulus of elasticity (5–10 times) and a decrease in the relaxation time. The conditions under which the structural changes arise depend on the content of potassium bromide and ammonia, and on the concentration of silver halide. Determinations were also made of the rheological characteristics necessary for the calculation of the optical drying regimes for emulsion coatings. — *S.C.G.* (*Translated from* Referativnyĭ Zhur., Fizika, *291*, *No. 8*, *1958*)

A Simple Method of Determining the Resolving Power of Photographic Materials

E. F. Pócza, *Acta Phys. Acad. Sci. Hung., 8:* 214–244 (1957) (in German)

A simple method of determining the resolving power of photographic materials is described. Onto the material to be studied is contact-printed a raster in which transparency varies according to a sine law. The advantage of this is that the results are independent of the properties of an objective. Beginning with some value of the frequency, the material no longer resolves the wave forms and they cannot be detected in the image. This limiting value of the frequency (it is identified with the resolving power) is easily found by observing the diffraction pattern given by the raster image on illumination from a slit by monochromatic light (Na: 589 mμ). The accuracy of the determination is ±10%. — *S.C.G.* (*Translated from* Referativnyĭ Zhur., Fizika, *298*, *No. 11*, *1958*)

Photoreproduction by Anodization of InSb

When InSb is made the anode in an appropriate electrochemical system, a transparent oxide film forms on the exposed surface. John D. Venables and Robert M. Broudy, of the Research Laboratories of National Carbon Co., Cleveland, Ohio, have observed that this anodization process is sensitive to visible light of wavelength shorter than about 520 mμ. Under appropriate conditions, the thickness of the oxide film is a function of the intensity of illumination, and projection of an image onto the face of the InSb sample undergoing anodization causes a permanent replica of the image to form on the surface. The contrast is provided by variations in interference colors corresponding to variations in the gray scale of the original picture. The procedure and an illustration of the results obtained are published as a letter to the editor, *Journal of Applied Physics*, *30:* 1110-11 (July 1959). The InSb used was single-crystal material of semiconductor grade, suitably polished. The electrochemical system consisted of the InSb anode, a graphite cathode, a reference probe also made of InSb, and an electrolyte of 0.1 *N* KOH solution. A constant current source was connected to anode and cathode, and the image was projected onto the anode by a 300-w slide projector. —*T.H.J.*

The Problem of the Critical Frequency of Intermittent Exposure

L. Zachoval, *Československ. Časop. Fys.*, *8:*18–22, No. 1 (1958) (in Czech)

Formulas obtained previously by the author for the photographic action of intermittent exposures are set out in a form allowing comparison with a series of experiments. Analysis of the data on the dependence of the effect of intermittent exposure on the length of the dark period, obtained by Maerker, and on the frequency of interruption, obtained by Kartuzhanskiĭ, and also on the latter's results on intermittent exposures at frequencies higher than the critical, showed their agreement with the author's formulas. It is also shown to be impossible to obtain the identical effect with an intermittent exposure and a continuous exposure with an intensity equal to the average intensity of the intermittent exposure, as stated by Webb. —*S.C.G.* (*Translated from* Referativnyĭ Zhur., Fizika, *294*, *No. 10*, *1958*)

A Study of the Edge Effect of a Photographic Image of a Bright Object

N. N. Shefov, *Gos. Astron. Inst. im. P. K. Sternberga*, pp. 66–73, No. 101–02 (1957)

A study has been made of the errors arising in the determination of the position of the boundary of the image of a bright macro-object on a photographic plate as a result of photographic edge effects due to scattering and development. Experiments have been carried out with two photographic materials (a lantern-slide plate and a graphic arts line material) on a model in the form of a test object consisting of two black-and-white bands, each 200 ± 0.1 mm wide. The densities of the image so obtained were measured on a recording microphotometer. It was found that the position of the true boundary can be determined by its density only for those densities which lie on the straight-line portion and the beginning of the shoulder of the characteristic curve. The essential influence then seems to be the density within the image: if it comes within the region of underexposure or over-exposure, location of the edge is untrustworthy, and with larger under- or over-exposures it becomes impossible. In principle it is wrong to find the true boundary by substituting for its measured profile a rectangular one equivalent to it in area and height, since the results will be different for different densities at the center of the image. — *S. C. G.* (*Translated from* Referativnyĭ Zhur., Fizika, *291*, *No. 8*, *1959*)

Photography on Photoelectrets

V. M. Fridkin, *Kristallografiya*, *2:*130 – 133 (1957).

A xerographic plate is made by vacuum evaporation of a thin film of sulfur. The plate is charged by flooding it with light while simultaneously applying a high potential. Because this state of charging can be regarded as similar to that obtained in an electret, Fridkin calls the resulting charged layer a photoelectret. There is, however, no reason to distinguish between Fridkin's charged sulfur layer and the more common selenium layers which can also be charged by the same means as well as by corona charging.

After contact exposure to a screened lithographic image, Fridkin developed it with a two-component developer, with asphalt as the positively charged toner and sand or salt as the carrier.

The same method of charging, which has elsewhere been termed induction charging, was used to sensitize 1-mm thick samples of unsupported sulfur. Opposite sides of this layer would then attract the different components of the developer. Anthracene was also tried. — *V. S. Mihajlov and H. E. Clark*

Photoelectrets and Formation of the Latent Electrophotographic Image

V. M. Fridkin, *Doklady Academii Nauk SSSR*, *118:* 273 – 276 (1958).

More than in the article cited above, here attention is paid to the sensitometry of xerographic development on sulfur xerographic plates. Fridkin attempts to draw a distinction between the process of electrophotography based on corona charging and that based on induction charging, but no evidence is presented to warrant this. He also attempts to relate the location of charge to crystal structure. — *V. S. Mihajlov and H. E. Clark*

Tekhnika Kino i Televideniya

Vol. 3, March 1959

Résumés by S. C. Goddard

Automatization of Correction for Film Shrinkage in Cine-Projectors with Optical Compensation

A. N. Tarasov, pp. 39–44

Projectors with optical compensation instead of intermittent pulldown have come into use in the transmission of films in television programs. Image quality in this type of projection can be considerably affected by shrinkage of the film, which not only varies from film to film but may not be uniform along a single film. Some form of automatic compensation for the shrinkage is needed. After considering the compensating mechanisms at present in use, e.g. in the E.M.I. and Bell Telephone telecinemachines, the author describes a simpler system in which a loop of film containing a standard number of perforations is held in tension by a roller on an axle which moves with variations in the length of the loop, and which actuates the optical system in such a fashion that variations in the size of the frame are compensated for by variations in the magnification of the projected image.

The Influence of Bleaching on the Quality of Sound Tracks on Color Positive Film

A. P. Strel'nikova and N. I. Kirillov, pp. 46–51

Experiments on the effect of bleaching during the processing of color-positive film on the quality of an optical sound track show that even a small degree of bleaching brings about a significant change in the effective density of the sound track, but if the sound track is given a preliminary black-and-white development, little change is observed. Highest quality sound tracks can only be obtained on color-positive film which does not contain colloidal silver as a yellow filter layer, the bleaching of which has an adverse effect on the sound track. In order to eliminate variations in the performance of different photoelectric cells, due to their different color responses, it is desirable to give the sound track a preliminary black-and-white development.

Tekhnika Kino i Televideniya

Vol. 3, April 1959

Résumés by S. C. Goddard

The Quality of Cine Film — On the Level of the Needs of Present Day Cinematography

E. N. Geller, pp. 1–4

Soviet motion picture film stock and its manufacture are criticized from the point of view of the user. It is difficult to assess from this article the quality of Soviet production in comparison with that of the West, since the criticisms are in general terms such as "too grainy," "too high a contrast," "speed should be doubled," and no numerical data are given. However, standardization of sensitometric properties is stated to be so unsatisfactory and the batch-to-batch variation so great that film studios are often forced to make a preliminary sorting and matching of the film before use. The keeping properties of the film, especially of color film, are also causing difficulties. The manufacture by the chemical industry of chemicals such as color couplers also comes in for criticism.

The Perception of Solidity and Distance of Objects in Ordinary Cine Films

V. A. Burgov, pp. 5–10

A sensation of distance and relief is often experienced when viewing non-stereoscopic pictures, still or cine. This phenomenon is considered from the point of view of the psychology of Pavlov as developed by Sechenov. In real life, distance and relief become associated with a number of visual appearances such as relative size, relative motion, geometrical perspective, aerial perspective, and shading, all independently of binocular vision which adds an extra refinement. The reproduction of these in the plane of the picture serves as clues to the spatial relations. The question is finally posed whether, in view of the large amount of spatial information already present in "ordinary" motion picture films, the extra expense and complication of stereoscopic and wide-screen films is justified.

Comparative Evaluation of the Quality of Photographic Images in Color

L. F. Artyushin and N. D. Nyuberg, pp. 11–19

When the possibility of an objective evaluation of picture quality in color photography is considered, it is found that at least 21 parameters must be taken into account: 9 specify the sensitometric properties of the material, 9 more the color separation, and not less than 3 are required to specify the complex of qualities going under the name of "sharpness." To connect these with visual estimates of picture quality in order to derive a means of measuring an "absolute picture quality" is not a practical proposition. A study has been made of the possibility of using fewer parameters: for this purpose 100 exposures were made of a standard scene, with variation in the color balance produced by filtering. By viewing prints made from the color negatives, the latter were placed in three classes — printable, not printable, and doubtful — by four observers. At the same time measurements were made of the "effective" densities of the three layers, defined as "the optical densities of a grey scale in the original, to which there correspond in the negative unit concentrations of dye per unit area." A three-dimensional plot of these qualities then allowed a region to be marked out enclosing the values of the effective densities for printable negatives.

Zhurnal Nauchnoi i Prikladnoi Fotografii i Kinematografii

Vol. 4, No. 2, March–April 1959

Résumés by S. C. Goddard

Theory of the Threshold Characteristics of Photographic Apparatus.
II. Requirements Arising in the Construction and Use of Photographic Apparatus

L. P. Moroz, pp. 81 – 89. (Part I, 3: 443 – 51 (1958); see *P S & E*, 3: 150 (1959)).

Some typical problems on threshold characteristics, arising in the construction of and use of photographic apparatus, are formulated and solved. An analysis of these solutions is given.

The Formation of the Latent Image Brought About by Depolarization of a Photoelectret

V. M. Fridkin, pp. 90 – 93

When a photoelectret is exposed to light, depolarization occurs and a positive latent image is formed as a "potential relief." The mechanism considered to be responsible in a dielectric, such as a monocrystal of sulfur, is the removal of electrons from the ground levels and local trapping levels into the conduction levels by means of the energy of the exposing light, with subsequent movement of the electrons under the influence of the internal field of the photoelectret to produce a local polarization in the opposite sense to that of the general polarization. A theoretical study of the second part of the mechanism has shown that the relation between the charge on the photoelectret and the time during which the depolarization process has been effective is not a simple exponential law, but can be represented to a first approximation as the sum of two exponents with relaxion periods $\tau = 1/k$ and 2τ. An experimental study of the depolarization current as a function of the light intensity for sulfur monocrystals has shown that such a photoelectret obeys the reciprocity law; but agreement with the above theory only obtains for part of the experimental curve, τ being equal to $1/k$ over the whole range, implying that the first process is the controlling factor.

The Influence of the Temperature of an Emulsion Layer on the Photographic Action of Electrons

I. A. Fomina, pp. 94 – 99

A preliminary study of the influence of the temperature of an emulsion layer on the mechanism of the photographic action of electrons has been carried out. It was found that when the temperature was lowered, the region of reciprocity failure was displaced in the direction of lower intensities, while the degree of departure from the law decreased. At a temperature of $-50°$ C the reciprocity relation was practically satisfied at all ranges of intensity used. A decrease in emulsion sensitivity was found when the temperature was lowered, the decrease depending on the intensity of the electron beam. The relaxion time τ was evaluated for each value of the temperature of the emulsion layer. An exponential relation is established between the relaxion time and temperature. On the basis of the results obtained, an evaluation has been made of the depth of the electron traps and of the frequency of thermal vibration of the electron in a trap. Values were obtained which were close to those which are characteristic of the photographic action of light. All the results obtained confirm the correctness of the basic assumptions, made in previous work, relative to the mechanism of the photographic action of gelatin. — (*Translation of author's abstract*)

A Study of the Processes of Aging and Stabilization of Photographic Materials
I. The Kinetics and Mechanism of Anomolous Aging of Photographic Materials

V. I. Sheberstov, pp. 100 – 105

Normal aging of a photographic material has all the appearance of a slow continuation of emulsion digestion, namely a slow increase of speed to an optimum, accompanied by a rise in fog which becomes rapid once the point of optimum speed is passed. Anomolous aging is characterized by a rapid fall in speed in the first month or two with very little increase in fog. Results of experiments on this type of aging are set out.

Incubation of photographic materials at a raised temperature and humidity, as a quick method of testing, was found to give results quite different from those of natural aging; an emulsion showed anomalous aging under natural conditions while it showed normal aging during incubation.

The Desensitizing Properties of Sensitizers

S. M. Solov'ev, 106 – 115

On treating sensitized photographic materials in a bath containing an oxidized sensitizing dye, the oxidized sensitizers act as typical desensitizers. While having practically no action on the latent image, they lower the general and induced sensitivity to an equal, or even greater, extent than the generally recognized desensitizers phenosafranine and pinakryptol green. On oxidizing a number of sensitizing dyes in bromine water and introducing them into unsensitized emulsions, the dyes lose their sensitizing properties to a greater extent, the greater the degree of oxidation. Different sensitizing dyes show different desensitizing properties on oxidation with bromine water, the greatest desensitizing action being shown by 3,3′ - dimethyl - 4,5,4′,5′ - dibenzo-9-ethyl-thiacarbocyanine chloride among the thiacarbocyanines studied. — (*Translation of author's abstract*)

The Photographic Activity of Gelatin Constituents
II. The Influence of Cations on the Digestion of a Photographic Emulsion

E. A. Zimkin and E. E. Garanina, pp. 116 – 120

It is shown that the rate of digestion of a photographic emulsion, other things being equal, depends on the valency of the cations of mineral impurities in the gelatin. In the presence of divalent cations, the digestion time required for maximum sensitivity is greater than with monovalent cations. It is suggested that the cations interact, during digestion, with intermediate compounds of silver ions and digestion accelerators. — (*Translation of author's abstract*)

The Determination of the Average Dimensions of Silver Halide Grains by the Light-Scattering of Emulsion Layers

P. Kh. Pruss, pp. 121 – 126

A photoelectric turbidimeter, measuring the light transmitted through an air-dry emulsion sample, was used to study the variation of turbidity with mean grain size. Ammoniacal emulsions gave a curve with a pronounced maximum, so that up to mean grain size of about 1 μ^2 a measured turbidity may correspond to two different grain sizes. The curve is displaced as colored filters are placed in the light beam, so that the ambiguity in the grain-size determination may be resolved by taking readings with differently colored light. Neutral emulsions gave a flatter curve with a less pronounced maximum, and are more difficult to use for grain-size determinations. The difference between the curves for the two different types of emulsion was so large that the curve for one type of emulsion should never be used for the determination of grain sizes of the other type.

Some Problems in the Use of Rotating Prisms as Optical Compensators

S. V. Kulagin, pp. 127 – 132

A mathematical analysis shows that absolute compensation for film displacement, i.e. complete equalization of the rate of displacement of the film and image, is not possible in cameras using a rotating prism. There is a residual relative motion which increases as the angle of rotation increases. This angle must be kept sufficiently small to prevent excessive lack of sharpness in the image, the permissible angle depending upon the thickness of the prism and the rate of displacement of the film.

The Reaction of Rhodacyanines with Silver Ions in Solution

K. I. Pokrovskaya (*Letter to the Editor*), pp. 133 – 135

The tendency of a number of rhodacyanines (merocyanines containing rhodanine) to interact with silver in solution increases with an increase in the basicity of the compounds. Those rhodacyanines which form silver complexes show a significant fogging action. Most of the dyes studied exhibited reversible complex formation, but certain pyridine derivatives combined irreversibly with silver ions. Symmetrical pyridorhodacyanines show evidence of two compounds with different dissociation constants.

The Influence of Hypersensitization with Triethanolamine and Ammonia on the Spectral Sensitivity of Photographic Materials

I. I. Breĭdo and A. A. Markelova (*Letter to the Editor*), pp. 135 – 136

Breĭdo had formerly stated that hypersensitization had no effect on the spectral sensitivity of photographic materials, but further experimental work has caused that statement to be revised. It now seems that materials fall into two categories: those in which hypersensitization by triethanolamine or ammonia produces an over-all increase in sensitivity; and those in which the sensitivity is preferentially increased in the regions of conferred sensitivity. Ilford HP3 alone of those tested comes into neither category, hypersensitization affecting the natural, unsensitized, sensitivity of the emulsion more than the conferred sensitivity.

The Role of Optically Forbidden Transitions in the Mechanism of the Absorption of Light by Silver Bromide

S. G. Ryzhanov (*Letter to the Editor*), pp. 136 – 138

At $\sim 20°$ K, optically forbidden transitions from the valency levels to the exciton levels play an insignificant part in the absorption of light by silver bromide, but they may explain the presence of the long and narrow "tail" of the absorption curve, stretching from 270 mμ to 450 mμ. When the temperature is raised to 300° K, a sharp increase in light absorption takes place owing to an increase in the frequency of forbidden transitions. The increase in forbidden transitions should also displace the exciton absorption from the ultraviolet into the visible as the temperature is raised.

The Limits of Photosensitivity of Silver-Halide Photographic Materials

K. V. Vendnovskiĭ and V. I. Sheberstov (*Letter to the Editor*), pp. 138 – 139

A calculation of the sensitivity of a silver-halide emulsion, expressed in the form of the reciprocal of the exposure energy per unit area required to give a density of D = 1 after development, leads to a value of $\sim 6 \times 10^3$ erg^{-1}cm^2, or to 25,000 (lux sec)$^{-1}$ when energy units are converted into exposure units. These figures assume that a single quantum is necessary to render a grain developable. A table gives the sensitivities for a range of numbers of atoms forming a developable center and for different numbers of electron traps in the crystal.

The Applications of Modern Photographic Techniques in Ophthalmology

E. G. Shaer, pp. 140 – 143

A short review article summarizes 70 publications on the subject.

Low-Intensity Reciprocity Failure of Modern Photographic Materials Used in Astronomy and Spectroscopy

I. I. Breĭdo, pp. 144 – 148

Data from 14 papers are summarized.

Advances in Soviet Electrophotography

K. S. Lyalikov, pp. 149 – 152

Papers presented to a conference held in December 1958 are summarized.

• Notes from the Editor

Personal Notes

Raymond Davis, who retired in 1958 as Chief of the Photographic Technology Section of the Optics and Metrology Division at the National Bureau of Standards, has served as consultant to that Division for the past year.

Irvine C. Gardner, an internationally recognized authority in the field of optics, retired on July 8, 1959, from the National Bureau of Standards where he was Chief of the Optics and Metrology Division.

Naoto Kameyama, Professor Emeritus of Tokyo University and one-time president of the Society of Scientific Photography of Japan, has been awarded the high honor of the Prize of Cultural Merit by the Japanese Government (November 1958).

Shinichi Kikuchi, Professor at Tokyo University and past president of the Society of Scientific Photography of Japan, has been awarded the Medaille Janssen of the Société Française de Photographie for 1959.

Herbert P. Paschel is the author of *The First Book of Color*, a brief primer of 38 pages of text and illustration recently published by Franklin Watts, Inc., New York. This book, well illustrated in color, gives an easy-to-understand introduction to the spectrum, absorption and reflection of light, the concept of primary colors, color printing, and some psychological factors in color preception.

Survey of Soviet Literature

A new survey of U.S.S.R. scientific publications, recently published by the National Science Foundation, states that 76 of the more than 2000 technical journals and serials issued by the Soviets are now translated into English, compared with 36 in 1956. Of the 76, 21 are in engineering and technology, 12 in physics, 9 each in chemistry, biology, and medicine, 7 in earth sciences, 3 in mathematics, and 2 each in agriculture, astronomy, and the social sciences. Besides the translations, the NSF report analyzes other Soviet primary sources of technical information — books, journals, and bulletins; and secondary publications such as review and abstract journals. The NSF will furnish copies of the survey, "Providing U.S. Scientists with Soviet Scientific Information," on request. Address: National Science Foundation, 1951 Constitution Avenue, NW, Washington 25, D.C.

Another complete journal translation has just been added to the list. On the initiative of the Optical Society of America, and with a NSF grant-in-aid, the Soviet journal *Optika i Spektroskopiia* is now being supplied in translation to the members of the OSA and to subscribers to the *Journal of the Optical Society of America*. The two journals are not available in separate subscriptions but only as a unit.

The Pencil of Nature

A classic of the photographic literature, William Henry Fox Talbot's "The Pencil of Nature," is republished in its entirety in the June 1959 issue of *Image*, the journal of the George Eastman House of Photography. The 24 illustrations are reproduced from prints which were found, excellently preserved, at Lacock Abbey, by Harold White, who is preparing a full-length biography of Fox Talbot. The issue of *Image* also contains a brief biography of Fox Talbot written by Beaumont Newhall.

Erratum

In the item on Professor Mott in *Notes from the Editor* in the last issue of *P S & E*, p. 177, "Calus" should read "Caius." — *T. H. James*

PHOTOGRAPHIC SCIENCE AND ENGINEERING
Volume 3, Number 5, September-October 1959

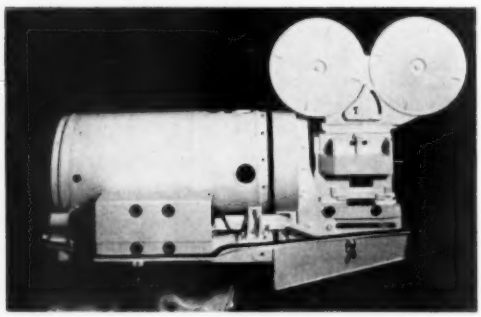
• New Products and Developments

FRANK SMITH

• Cameras and Accessories

L-W Photo Products Co. 35mm Cine-Pulse Camera with Automatic Exposure Control

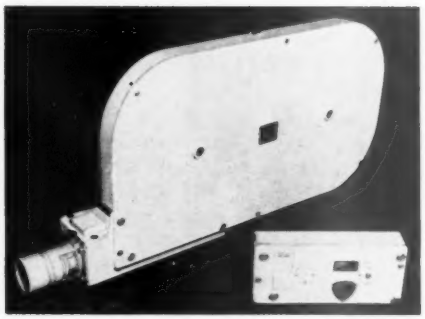
L-W Photo Products Company, Northridge, Calif., has announced development of a 35mm cine-pulse camera with automatic exposure control. The camera is a pin-registration 35mm intermittent movement camera, with frame rates of 20, 40, and 80 frames/sec, plus pulse operation at a rate governed by an external 28-v dc signal. Through-the-lens viewing, a focusing mount, timing lights, a correlation switch to provide an output pulse at the midpoint of the shutter opening, fiducial markers installed at the aperture, and a data box which permits the photographing of four instrument dials on the edge of the film are provided. Automatic exposure control is accomplished by means of a photocell-controlled circular neutral-density wedge mounted in the optical system. Quick response is a feature of this system.



The photograph shows the camera, 300cm lens, mount, and data box.

Photo-Sonics Long-Run 16mm High-Speed Prism Camera

A new 1200-ft film magazine for the Photo-Sonics 16mm-1B high-speed rotating prism camera permits operation for a full 50 sec at a rate of 1000 frames/sec. Featuring stop-start capability at any point in the film roll, the camera is used in rocket engine test work, where the difficult requirements of high resolution, high framing rates, and long running times are imposed. A disc shutter located behind the prism and

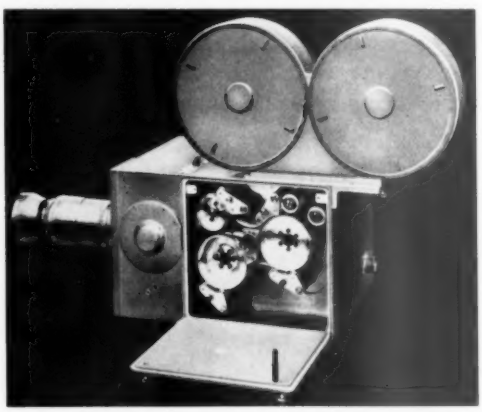


turning in synchronism with it masks off the less desirable portions of the image transmitted through the prism, and results in high-speed motion pictures that closely approach in resolution those obtained from precision intermittent-type motion picture cameras.

The camera is distributed by Traid Corporation, 17136 Ventura Blvd., Encino, Calif.

Photo-Sonics High-Speed 70mm Camera

Traid Corp., Encino, Calif., has announced the new Photo-Sonics 70mm – 10B Rotary Prism Camera which uses the same prism-shutter combination as the 16mm – 1B and the 35mm – 4B cameras. Up to 360 full-frame 70mm pictures ($2\frac{1}{4}$ in. by $2\frac{1}{4}$ in. negatives) per second (70 ft/sec) is the taking rate of the new camera. Missile launching and tracking, photography of the separation of booster motors from missiles and rockets, and high-resolution streak

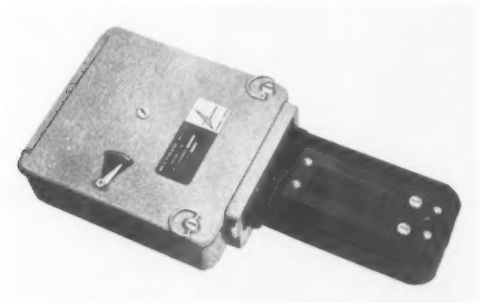


Although the information contained in this section is compiled from sources believed to be reliable, the author cannot assume responsibility for its accuracy. Publication of the information here is not to be construed as an endorsement or recommendation of the product or equipment described.

photography are some of the applications for this camera. Long focal-length lenses can be used with low vibration levels.

Flight Research 200-ft 16mm Film Magazine

Flight Research, Inc., Richmond, Va., has announced a 200-ft magazine, M-1, for use with the 16mm Model III and III-B Multidata Recording Cameras. The magazine uses the same film transport as the 800-ft M-3 magazine and can be loaded in subdued light with standard daylight loading spools.



• Illumination

Sun-Lite Hi-Pro Electronic Flash

A new electronic flash has been announced by Hershey Mfg. Co., 4309 W. Lake St., Chicage 24, Ill. It has 150 w-sec of light output, 4000-beam candle-power-sec, Kodachrome Guide Number of 90, and built-in photocell for slave operation. It is also equipped with a modeling light and has a recycling time of 6 sec. The unit measures 6 in. by 6 in. by 6 in. and weighs 4½ lb. Accessories available are a swivel bracket, barn doors, and light stands.

• Optics

Singer Military Products Division Repli-Kote Mirror

A low-cost method of producing cast plastic reflective optical components has been developed by HRB Inc., State College, Pa., research and development branch of The Singer Military Products Division. A negative which is cast from a precision ground-glass master mirror is used as a mold for casting positive replicas. Both negative and finished product are made of a special epoxy resin formulation. The reflective surface is an aluminum coating applied in high vacuum and overcoated with a protective film.

An advantage of the process is that complex aspheric surfaces can be mass produced.

• Processing Equipment and Techniques

Cormac "Unibath" Processing Solutions

The Cormac Chemical Corp., 80 Fifth Ave., New York, N.Y., has announced eight new one-step processing solutions, called Unibaths. The solutions and their uses are as follows: CC-1 and CC-2, films; CC-3, paper; CC-4, x-ray film; CC-5, lithographic materials; CC-6, motion-picture positive film; CC-7, microfilm; and CC-8, oscillograph films and papers. CC-1, CC-2, and CC-3 are being marketed immediately.

According to the company, Unibath combines both the developing agent and the fixing agent. Processing in the single chemical bath is followed by a short water wash. Since the bath contains its own hypo-neutralizing agent, there will be little or no residual hypo in the negative or print. A series of Unibath products in liquid, dry powder, and even in thick gelatin form (for use in airborne darkrooms where tank spill must be minimized) are planned by the manufacturer.

• Projection

Mast Development Co. Precision Film Transport

The Mast Development Co. Inc., Davenport, Iowa, Model 100-1 Film Transport is a projector, complete with a base plate for mounting, for the precision projection of 35mm single-frame microfilm and data film. It is built primarily to replace the standard head of the Model C Recordak Film Reader, but can also be adapted to other projection applications. It employs a film advance which is a modification of the Bell & Howell movement, and features pin location of the film to within ± 0.0005 in. longitudinal and transverse accuracy. Film can be run in forward or reverse directions at 3½ to 24 frames/sec. Single-frame advance is made at the slower speed to avoid film damage. Maximum film capacity is 200 ft. The film aperture measures 0.720 by 0.960 in. The projection lens is the $f/2$, 45mm Kodak Ektar lens normally supplied with the Recordak Film Reader. Magnification can be varied from 15× to 20×. Optional projection alignment features available include 360° rotation and $\frac{5}{8}$ in. azimuth and elevation motions of the projection head.

• Reproduction and Copying

Peerless Continuous-Flow Enlarging and Reducing Cameras

A camera which will enlarge opaque or translucent originals on a continuous-flow basis and a redesigned Collins-Peerless Neoflow Continuous Reducing Camera, which reproduces large engineering drawings in reduced size, have been announced by Peerless Photo Products, Inc., Shoreham, N.Y.

The Neoflow Enlarging Camera (at left in illustration) operates on a continuous-flow principle and uses the reflex photocopying method. The original moves continuously across a lighted slot; the image travels along a light path through a sequence of mirrors and an enlarging lens until it reaches the sensitized material on which the copy is made. The sensitized material is moved in exact synchronization with the image of the original. The lighting system consists of a single GE 20-in. 1800-w high-pressure mercury-arc tube with the necessary transformer and high-velocity fan-cooling system. Dimensions are: height, 8 ft 9 in.; width, 6 ft; length, 6 ft. The weight is 1900 lbs.

The new Neoflow Reducing Camera (at right in illustration), like the earlier versions, operates on a continuous-flow principle and uses the reflex photocopying method. The camera can copy originals up to 42 in. wide at speeds up to 25 ft/min. The camera offers seven reductions: 2:1, 3:1, 3½:1, 4:1, 6:1, 7:1, and 8:1. The lighting system, consisting of seven fluorescent tubes, is arranged so that the operator can select any number of lights, according to the type of original. The dimensions and weight of the reducing camera are the same as those of the enlarging camera.

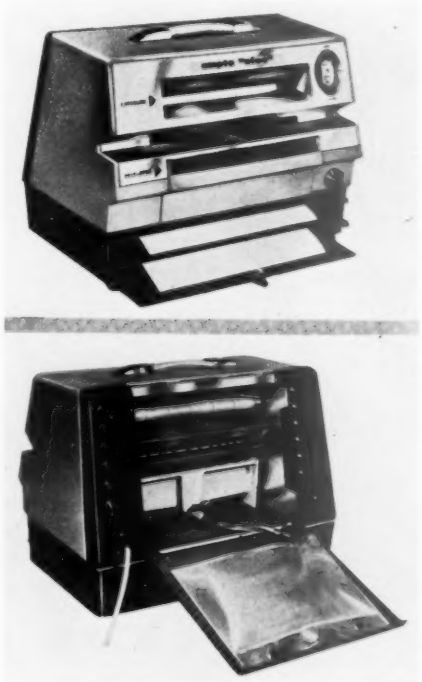
Anken "Plenacopy" Photocopying Process

Anken Chemical and Film Corp., Newton, N.J., has announced development of a new emulsion and a new processing solution which allow existing diffusion transfer machines to be used for making multiple copies. The process can be used with most standard diffusion transfer machines by adding a second processing tray of the new Anken Monobath solution. Where a second tray is impractical, a processing unit called the Plenamatic can be used.

Using a regular photocopy machine and papers, a standard transfer print is first made, using Ampto Standard or Lumolite negative. After peeling, the negative is dried in subdued light. The Plenacopy paper is then used to make prints of the negative, which are processed in the monobath. Because the Plenacopy paper is exposed by the print-through method, the negative may be transparentized for shorter exposures and sharper images.

Ampto "Nine" Multiple-Purpose Copier

The development of a new 9-in. portable photocopier for office and engineering-reproduction de-

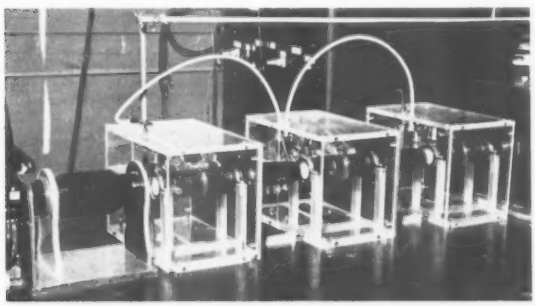


partment use has been announced by Ampto Inc., Newton, N.J. The new unit will handle papers and films up to 9 in. wide by any length. The copier can be used for straight diffusion transfer (peel-apart) exposures and processing, and with the new single-sheet Plenacopy process whereby unlimited numbers of copies can be made from a single negative. The copier can also be used to make positive films for use with positive plates for offset printing, diazo reproduction intermediates, and transparencies for visual (overhead) projectors.

• Miscellaneous

Photography of Cosmic Ray Tracks with a Cascade Luminescent Chamber

A new instrument for the study of high-energy nuclear-particle interactions has been developed by Professors Lawrence W. Jones and Martin L. Perl of the University of Michigan. With the new device, the paths of charged particles (protons, electrons, etc.) are recorded by the light they produce in passing



through solid materials such as certain plastics and crystals. While this light is a hundred-thousand times too faint to be detected by the unaided eye or to be photographed directly, special image intensifying electronic tubes can be used to amplify the faint light to a level where it can be seen and photographically recorded.

The luminescent chamber has the advantage of permitting the use of an electronic gate or shutter to select events in time to within intervals as short as 1 μsec.

Film Ratings vs Forced Development Studies by Kodak

Film-speed ratings and the factors that contribute to quality in black-and-white picture taking are explored in a new publication, *Photographic Quality vs Forced Film Speeds*, Pamphlet F-17 of the Eastman Kodak Co., Sales Service Division, Rochester 4, N.Y.

The booklet reports on an experimental project conducted by the Kodak Research Laboratories to find answers to these questions:

1. How does a photographer intelligently rate film in terms of his subject?
2. How far can he go in the direction of underexposure before quality begins to suffer noticeably?
3. What can be accomplished by forced development?
4. How does forced development affect photographic quality?

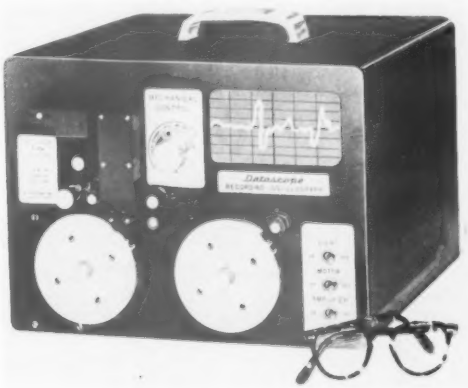
Illustrated with photographs and graphs showing the relation of quality to the assumed exposure index, the publication reports on results obtained when six scenes representing extremes in brightness scale and illumination level were photographed at varying exposure indexes.

Kodak Booklet on Photography of the Heavens

Astrophotography with Your Camera, Pamphlet C-20 of the Eastman Kodak Co., Sales Service Division, Rochester 4, N.Y., is a 16-page booklet which describes the principles of astronomical photography and exposure determinations and offers detailed recommendations on the equipment needed for this field of photography.

Datascope Recording Oscillograph

A recording-projecting oscillograph has been announced by Microsound, Inc., 4627 Leahy St., Culver City, Calif. The instrument records transients ranging up to 5000 cps on a narrow plastic tape which is immediately projected within the instrument onto a 4-in. viewing screen. The tape can be trans-



ported backward and forward for detailed visual inspection. The record can be projected directly from the instrument to a wall screen, or important sections may be photographed. Accessories include an interchangeable dual channel head, a unit which permits the recording of higher frequency signals up to 200,000 cps, and a pulse timing head and amplifier to record a visible time blip parallel to the signal trace. The instrument measures 9 in. high, 12 in. wide and 8 in. deep and weighs less than 15 lb.

Kalart Motorized 16mm Editor-Viewer

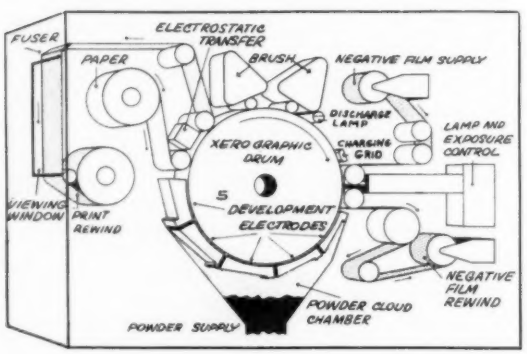
A new 16mm motion-picture editor-viewer with motor-driven film advance mechanism has been announced by the Kalart Co., Plainville, Conn. The major advantages of the editor-viewer are its compact design, picture quality, and convenience of set-up and operation which permit its use in showing full-length 16mm silent motion pictures on a $3\frac{1}{2}$-in.

by $4\frac{1}{4}$-in. hooded viewing screen to small groups in situations where it is impractical or inconvenient to darken a room and handle a regular 16mm projector and screen. The device has a three-position control which permits automatic film advance at 24 to 26 frames/sec, single-frame viewing without the need for hand adjustment to bring the frame into position, and manual operation. Maximum usage of the light from the blower-cooled 75-w lamp is provided by coated optics which include a 3-element $f/2.8$ projection lens, condenser lens, and four-sided rotating prism. The viewer has a reel capacity of 400 ft and weighs under 12 lb complete with carrying case.

Air Force Xerographic Automatic Picture Printer

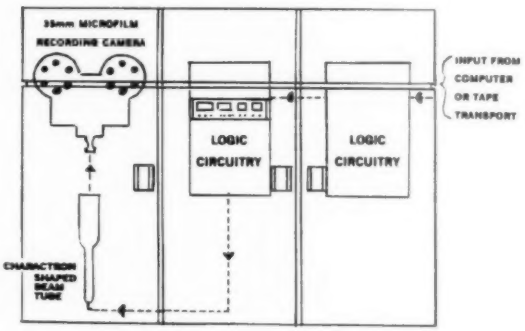
A printer which makes inexpensive finished pictures in seconds from photographic negatives by a high-quality dry process has been developed by Haloid Xerox Inc., Rochester, N.Y., for the U.S. Air Force. Printing by the xerographic method directly from conventional aerial negative films, the device automatically exposes, prints, and finishes dry, positive continuous-tone pictures on inexpensive, white, unsensitized paper at the rate of 20 ft/min, making a different 9-by-9 in. print every $2\frac{1}{4}$ sec. A 500-ft roll of negative film up to 9 in. wide is used. The process is flexible so that with a simple adjustment the self-contained unit can also make positive pictures from positive film. The new machine is designed primarily for use in high-speed high-volume printing from aerial film for mapping and reconnaissance purposes.

By the xerographic process this machine makes possible viewing of the finished prints a few seconds after picture making begins; also rapid modifications of contrast and exposure can be made continuously while the machine is running. The printer can be operated continuously in radioactive environments.



Stromberg-Carlson High-Speed Microfilm Printer

Equipment capable of recording computer output data on microfilm at the rate of 15,000 characters/sec has been announced by Stromberg-Carlson, Division of General Dynamics Corp., San Diego, Calif.



The computer output data is used to generate appropriate characters on the face of a Charactron shaped-beam cathode-ray tube, and these characters are then photographed on 35mm microfilm. The unit is 66 in. wide, 34 in. deep, and 72 in. high. Among accessories offered for use with the S-C 4020 is the F-20 Automatic Processing Camera-Projector which permits viewing of selected data within 10 sec of its appearance on the face of the tube.

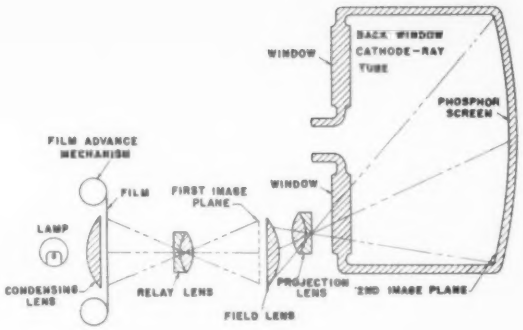
IBM Back-Window Cathode-Ray Tube

The International Business Machines Corp. Computer Laboratory has developed a 10-in. cathode-ray tube with which electronic and pictorial data are displayed on a common screen. The pictorial data, contained on a 35mm film strip, is optically projected through a window in the rear of the tube onto the phosphor viewing screen for comparison with the electronic display. Conventional cathode-ray tube phosphors provide optical screens exhibiting excellent resolution and viewing angle characteristics.

The precision of present electronic displays justifies the need for a high quality display comparator.

Precision comparators have application in radar guidance systems, both military and commercial, where route maps, airport traffic patterns, or other optical information superimposed on the electronic display will aid the operator in interpreting the radar image.

The back-window design may also be used to record photographically the electronic or combined electronic and optical display. Photography through the rear of the CRT can be accomplished with an optical system similar to the one used for projection. Photographing from the rear of the phosphor screen gives an advantage in brightness and resolution over conventional photography from the front.



1959 National Conference

26 to 30 October

Edgewater Beach Hotel · Chicago, Illinois

The next National Conference of the Society has been scheduled for October 26 through 30, 1959, at the Edgewater Beach Hotel, Chicago, Illinois.

In this Conference of international scope a record number of 70 papers will be presented on a wide range of photographic subjects by scientists and engineers representative of university, military, and industrial organizations. Complete abstracts will be found on pages 248–256 of this issue.

Forms for advance registration have been mailed to the Society's membership. Additional copies can be obtained from Mr. Joseph Mangiaracina, 30 Brook Avenue, Little Silver, New Jersey.

PHOTOGRAPHIC SCIENCE AND ENGINEERING
Volume 3, Number 5, September-October 1959

• Advance Program—1959 National Conference

Society of Photographic Scientists and Engineers

Members of SPSE and non-members are invited to participate in the 1959 National Conference which will be held from October 26 through 30 at Chicago's famous Edgewater Beach Hotel. As you can see from the following program schedule of papers and events, we have an unprecedented number of highly informative papers covering a wide range of scientific and engineering subjects. Every effort has been made to group the papers and arrange the sequence of sessions for the convenience of those attending.

At this time, the program is as complete and accurate as possible, but experience has shown that minor departures are unavoidable.

Monday Morning, October 26

Military Photography

Is There a Future for Photo-Optical Instrumentation in Missile Testing? *C. W. BEMISS, RCA Missile Test Project, Patrick Air Force Base, Cocoa, Fla.*

During the first ten years of missile testing, determination of acceleration, velocity, and flight positional information has depended to a large extent upon photo-optical systems of various configurations. However, the more stringent requirements, dictated by our latest "refined" missiles and orbital vehicles, for greatly improved accuracy and immediate availability of metric data indicates a trend toward dependency on electronic systems unless a major break-through is achieved in the photo-optical "state of the art." This paper documents the future requirements which must be met—as a challenge to the photo-optical industry.

An Evaluation of a Cinetheodolite Data Production System Including the Contraves EOTS and the Askania Kth 53, *CHARLES W. MULLIS, White Sands Missile Range, N. Mex.; S. M. LIPTON, J. W. Fecker Inc., Pittsburgh, Penna.*

The plan for evaluation of a system including the two cameras is explained. The instruments, calibration procedure, data-collection system, and data-reduction system are described. Problems encountered in the collection, reduction, and analysis of the data are presented. The statistical treatment is discussed and the results are given.

Performance of the Space Photographic System, *G. G. HART, W. F. HALL, H. A. SCHEETZ, and J. BOMSTEIN, Cornell Aeronautical Laboratory, Inc., Buffalo, N. Y.*

A result of a continuing study* of the physical characteristics of photography from space vehicles is the qualitative arrangement of the primary parameters in nomographic form. The image spread and contrast reduction resulting from each of the elements of atmospheric scattering and turbulence, diffraction by the camera aperture, lens aberrations, and film granularity have been determined. These have been cascaded to present the final image in terms of detectable and recognizable threshold dimension and contrast. The sequence provides a systematic measure of the inherent physical limitations and indicates requirements for more detailed investigation in specific areas. An illustrative example is given which provides a preliminary estimate of the performance of a system and indicates the influence of image-motion control as a function of vehicle stabilization and orbital motion. Applications to lunar and planetary exploration in addition to terrestrial reconnaissance are discussed.

*Contract AF33(616)-5870, Aerospace Reconnaissance Laboratory, WADC.

A Mathematical Performance Model for Aerial Reconnaissance Systems,* *RAYMOND F. MISSERT, Cornell Aeronautical Laboratory, Inc., Buffalo, N. Y.*

A mathematical description of the performance characteristics of complete aerial reconnaissance systems has been formulated in the form of a digital computer program, utilizing the concept of the system transfer function. A description of the operational modes of the computer program will be presented with a discussion of new data derived for input to the model which accounts for the characteristics of the atmosphere, camera lenses, vehicle motion effects, and interpretability relations. The evaluation of the computer output in terms of the information-gathering capabilities of the system will be presented, together with a new image-quality criterion for the detection and recognition properties of the system.

*Developed under Contract DA-36-039-SC-74910 with the United States Army Signal Research and Development Laboratory, Fort Monmouth, N. J.

Photosensitive Materials for the Preparation of Molded Photosurface Terrain Models,* *HARRY L. FICHTER, MALON H. DICKERSON, and R. H. SPRAGUE, Horizons Inc., Clereland, Ohio.*

Photosensitive negative and print materials are described which retain sensitivity during a heat-molding cycle. The negative material is silver-halide sensitized and is exposed by orthogonal projection to produce a master negative. The master negative is used for contact printing of similarly molded, iron-salt-sensitized print materials. Each type of emulsion is prepared with polyvinyl alcohol, coated on a film base having the required heat-molding characteristics.

*The work reported was performed under Contract N 61339-57 for the U.S. Naval Training Device Center, Port Washington, New York.

Monday Afternoon, October 26

Cameras and Technique

The KS-50 Panoramic Camera (Hi-Acuity), *SAUL R. LEVINE, Fairchild Camera and Instrument Corp., Syosset, N. Y.*

The development of the KS-50 panoramic camera subsystem is an attempt to keep pace with the present and future demands placed upon photographic reconnaissance

systems. Its aims are to provide a high-acuity photographic system and to improve the intelligence-gathering efficiency so that the total data collected per pound of system weight will be greater.

The subsystem consists of a twin-scan, stationary-film panoramic camera and mount capable of 80 lines/mm performance with an angular coverage of 150°. Film capacity is 2500 ft of standard base or 5000 ft of thin base 9½-inch, non-perforated film. Image motion compensation and momentum balancing techniques are employed. The lens utilized will be a 24-inch focal length, *f*/5.6. Shutter speeds are available from 1/50 to 1/800 second with automatic exposure control provided. Steadiness to 3 sec of arc during any 1/50-second exposure will be provided by the mount, which has ±8 degrees of freedom in pitch, roll, and azimuth.

A New Multi-Purpose 4½ x 4½ Aerial Camera, *EUGENE W. ELLIOTT, Chicago Aerial Industries, Inc., Melrose Park, Ill.*

A compact 4½ x 4½-inch aerial camera has been developed as a component for modern aerial photographic reconnaissance systems. It provides three modes of operation including: (1) moving-film image-motion compensation up to 10.8 inches per second at a rate of 6 exposures per second; (2) capping-shutter night photography with image-motion compensation; and (3) an efficient intra-lens shutter coupled to the lens diaphragm. Both the shutter speed and lens aperture are continuously variable to produce a normal exposure over a range of light level and emulsion sensitivity. Interchangeable lens cones provide focal lengths to suit desired scale and ground coverage. The camera supplies velocity and positional electric-feedback signals compatible with the control circuits of automatic and semi-automatic camera control systems.

A High Resolution Catadioptric Aerial Camera, *LEON N. ZECHIEL, General Precision Laboratory, Inc., Pleasantville, N. Y.*

A camera developed for airborne stellar photography and the application of a precise photogrammetric technique for determining aircraft orientation from photographs of stars are described. The camera optics consist of a relatively high-resolution catadioptric system of large aperture and medium focal length. The camera body is basically a 70mm motion-picture camera, modified for time-lapse short-exposure technique. Supplementary data are photographed on each frame through an auxiliary optical system. The peculiar problems of photographing stars from an aircraft and the possibility of applying similar equipment to other tasks are discussed.

Critical Design Problems for Instrumentation Cameras, *GUY H. HEARON, Benson-Lehner Corporation, Los Angeles, Calif.*

In the design of a strike camera for the Convair F-106, the major problems were: (1) providing a 1 x 3-inch format at a frame rate of 20 per second; (2) packaging the camera so it would fit into the very thin leading edge of the plane's wing; (3) designing an adjustable optical system which could always be directed toward the line of flight, regardless of the inclination of the plane; (4) building right- and left-hand versions of the camera, to be mounted in both wings of the plane in such a way that they would give a combined, wide-angle view; (5) overcoming environmental conditions such as vibration, severe G-loads, extremes in temperatures, and high altitude; and (6) wiring the camera so it would be suitable for both 200-volt, 400-cycle alternating current and 28-volt direct current. This paper describes how these problems were solved.

Multiflash Photography, *HAROLD E. EDGERTON and FREDERICK E. BARSTOW, Edgerton, Germeshausen and Grier, Inc., Boston, Mass.*

There are many good reasons why electronic flash lighting is especially useful for multiple-exposure photography: the flash interval can be accurately controlled; the initiation time can be precise; the exposure time can be controlled; the exact quantity of light can be determined.

In this paper, several typical electric circuits for electronic-flash lighting are discussed, with special emphasis on a combination operated at up to a 100-kc rate. A one-microsecond flash duration with 1.5 watt-seconds per flash is used.

100,000- to 400,000-Frame-Per-Second Color Photography, *W. O. S. JOHNSON, E. I. du Pont de Nemours and Co., Inc., Mechanical Development Laboratory, Wilmington, Del.*

A portable ultra-high-speed camera has been developed which is capable of taking 100,000 to 400,000 pictures per second, thus providing an enormous magnification of the time scale of very rapid events. The use of lenticular plates as the image-dissecting elements of the camera provides extremely high light-gathering efficiency, making it possible to photograph such events in color. The camera, the special electronic lighting, and control equipment which have been developed, and the techniques which have been developed for fabricating and using the color-sensitive photographic plates will be discussed.

High-Speed Cinemicroscopy of Electrically Exploded Tungsten and Molybdenum Wires,* *L. ZERNOW, G. WOFFINDEN, and K. KREYENHAGEN, Aerojet-General Corp., Azusa, Calif.*

Cinemicroscopic observations of electrically exploded tungsten and molybdenum wires, having diameters of one to three and one-half mils, have been carried out at framing rates up to 1.2 x 10^6 frames per second and magnifications of about 25×.

Both undulant and striated breakup modes were observed. The growth of vapor bubbles inside the molten wire is an important factor in the striated breakup mode. An animated film of exploding wire sequences illustrating these points will be shown. Other applications of high-speed cinemicroscopy will be discussed briefly.

*Sponsored by Office of Ordnance Research, Durham, North Carolina, under Contract DA-04-495-ORD-1407.

Monday Evening, October 26

Data Handling

A New Minicard Document Camera, *BRUCE L. ELLE, Eastman Kodak Co., Rochester, N. Y.*

A new document-recording camera is described which creates the original film record of the Minicard system and is capable of recording both graphic information and digital code. A maximum of twelve 8½ x 14-inch documents can be photographed on a single Minicard film record. Film is exposed in rolls and is cut after processing into the individual Minicard film records approximately 32mm long by 16mm wide. A special 16mm, *f*/4 document-recording lens operating at 60× reduction is used. The system is capable of producing essentially diffraction-limited resolution.

Code information input originating in a punched paper tape is read by a high-speed reader into a tape-to-target transfer logic which stores the character data and transfers it in bit parallel fashion to the code target. The code target transforms the stored data into an optical display for recording on the Minicard film record.

The Minicard Camera Code Target, *EDWARD W. FORMAN, Eastman Kodak Co., Rochester, N. Y.*

The Minicard code target is an electro-mechanical-optical device which acts as a transducer of the electronic information held in the solenoid drivers of the tape-to-target transfer logic of the Minicard Camera. It converts this information into an optical display capable of being photographed onto the Minicard film record. This display consists of a line (column) of 43 rectangular, independently shuttered bits plus an unshuttered timing mark.

The code target display is projected through an optical

system at 8.299 times reduction onto the Minicard film record. The light source is an E.G. & G. type FX-1 flash lamp. The target is capable of operating up to 20 columns per second.

Photographic Problems Associated with the Construction of a Large Computer Memory, *M. B. PURVIS and G. V. DEVERALL, Bell Telephone Laboratories, Inc., Whippany, N. J.*

Megabit photographic memory with random access in a few microseconds to a seventy-bit word has been constructed for use in a digital computer. The nature of the memory system is presented. The optical discrimination ratio is discussed as a function of the various optical and photographic problems which affect performance. Test methods used on principal optical components are presented and sample results shown. The construction of the photographic elements in a closed-loop beam-positioning system is discussed in terms of the photographic procedures used to control precise ($\pm .0003''$) image location.

The Design of a High-Speed Optical Scanner for Reading Minicard Film Record Code, *ARTHUR E. NEUMER and DUANE E. GRANT, Eastman Kodak Co., Rochester, N. Y.*

The code field on a Minicard film record consists of a series of columns of 43 exposed or clear bits. In one form of scanner which is described, a spherical mirror images one complete column of code on an array of 43 Ektron detectors. The spherical mirror is rotated so that a complete film record containing a maximum of 64 columns is scanned in approximately 19 milliseconds. An improved model, which is also described, uses a plano scanning mirror with an all-refracting optical system. Silicon cells having a peak sensitivity at approximately 8.5 millimicrons are used in place of the lead sulfide Ektron detectors. Tracking errors are held to less than 0.001 inch.

Board of Directors Meeting

Tuesday Morning, October 27

Sensitometry

Continuous-Tone Characteristics of Kalfax Film, *EDWARD S. COBB, U. S. Naval Photographic Center, Anacostia, Washington, D. C.*

Kalfax film has been used primarily for line-copy work, but its entirely dry processing and insensitivity to nuclear radiations have led the U.S. Navy to investigate its sensitometric characteristics for the reproduction of continuous tone. The emulsion is a transparent plastic carrying a silver-free light-sensitive substance which produces an image composed of microscopic bubbles. The image is colorless and, because of its dispersion of light rather than absorption, it can be viewed as a negative or positive, depending on whether it is viewed by reflected or transmitted light. The film is developed by heat and "fixed" by exposure to ultraviolet or daylight.

Data will be presented on the resolution capability, diffuse-density tone scale, exposure range, gamma, Callier-Q factor, and other properties related to recording and viewing continuous-tone photographs.

An Automatic Gamma-Ray Sensitometer Using Cobalt-60 Foil Sources, *V. G. McININCH and H. M. CLEARE, Eastman Kodak Co., Rochester, N. Y.*

A sensitometer is described for exposing film between lead-foil intensifying screens in a four-step sensitometric series, using thin cobalt-60 foils as the radioactive sources. With source activities totaling about seven millicuries, exposure times for industrial-type x-ray films range from 10 to 200 seconds.

Film samples in lead-screen cassettes are stacked in a hopper outside the source shielding and, in sequence, are automatically transported to the exposing position, exposed, and discharged outside the shielding. The shielding is sufficient to reduce the radiation intensity to a factor of two or three above background. The mathematical theory of the design of the sensitometer is also presented.

The Effect of Gamma-Ray Exposures on Camera Films, *G. M. CORNEY, Eastman Kodak Co., Rochester, N. Y.*

Circumstances under which it is necessary to perform photography in relatively intense fields of penetrating radiation are becoming increasingly numerous. The effect of an over-all gamma-ray fog is to raise the toe of the characteristic curve, thus decreasing contrast. In addition, the graininess of the developed image increases with increasing gamma-ray exposure. These effects are illustrated, and the points to be considered in choosing a film for use in the presence of gamma rays are discussed. In many cases it is possible to obtain a useful photographic record in the presence of a high degree of fog, due to penetrating radiation.

Sensitometric Evaluation with Basic Data Processing Equipment, *STANLEY M. ROGGE, Ansco, Binghamton, N. Y.*

The paper describes the automatic recording of sensitometric data on punched cards and some of the uses which are made of it, utilizing a basic system of IBM data processing machines.

This system is in use at the present time primarily as an aid in the immediate evaluation of manufactured film of all types. Its advantages lie in the speed and accuracy of reports to the production areas and in the great increase in the amount of prior information available to the product evaluator.

A Nomograph for Selecting Light-Balancing Filters for Camera Exposure of Color Films, *C. S. McCAMY, National Bureau of Standards, Washington, D. C.*

A nomograph has been designed for rapid selection of filters to adjust the spectral quality of the illumination to match the spectral sensitivity of the film for color photography. The nomograph provides for a very large number of combinations of films and light sources in a simple form; permits the easy interpolation of new films, light sources, or filters; indicates which filters would be satisfactory when an ideal filter is not available; indicates the general nature of abnormal combinations for special effects; and provides a convenient conversion from color temperature to reciprocal color temperature. The nomograph is based upon the assumption that the color balance of color films, the chromaticity of the illumination, and the effect of filters can be characterized adequately on a scale of reciprocal color temperature and that the change of reciprocal color temperature by a given filter is a constant.

A Glass-Screen Halftone Sensitometer, *RAYMOND ALFAYA,* Photo Products Department, E. I. du Pont de Nemours and Company, Inc., Parlin, N. J.*

Exposure of halftone dot patterns on film test samples is required in the evaluation of "lith" type films and processing systems used in the graphic arts industry. Though a process camera equipped with a cross-line glass screen can be used for making halftone exposures which are representative of practical application, this type of equipment is cumbersome and inconvenient for experimental and test use.

A simple, compact optical system is discussed which will effectively simulate any set of optical conditions that can be obtained with a process camera. A prototype halftone sensitometer using this system is described.

*Mr. Alfaya is now associated with Kearfott Company, Inc., Clifton, New Jersey.

Tuesday Noon, October 27

Welcoming Luncheon

Tuesday Afternoon, October 27

Tone Control and Special Effects

A Sensitometric Method for Measuring the Masking Effect of Dodging Printers, *KARL LEISTNER, U. S. Army Signal Research and Development Laboratory, Fort Monmouth, N. J.*

The sensitometric basis of dodged printing is discussed. A method is shown for finding the "masking coefficient" from purely photographic data, as well as a method for graphical presentation of the process, using a modification of Jones' diagram of tone reproduction. Data from existing printers of both types, feedback scanning and phosphor quenching, are shown. Some implications of the addition of local, small-area contrast control to automatic dodging are discussed.

Signal Corps Automatic Electronic Contact Printer Type EN-39, *WILLIAM D. MATTHEWS, U. S. Army Signal Research and Development Laboratory, Fort Monmouth, N. J.; KENNETH H. FOLSE, LogEtronics, Inc., Alexandria, Va.*

An automatic step-and-repeat photographic contact printer, Type EN-39, utilizing electronic exposure control, automatic electronic dodging, and capable of exposing twenty-five 9 x 9-inch prints per minute has been developed. From normal negatives, exposure times in the order of 1 second are achieved on variable-contrast projection paper when filtering to produce medium-high contrast. Electronic velocity-modulation dodging and/or exposure control contributes to increased efficiency with the use of fast optics in projecting the printing raster. A special phosphor material on the face of the tube matches the spectral requirements of the paper and a normal-contrast filter arrangement minimizes light loss.

LogEtronics and Color, *DWIN R. CRAIG, LogEtronics, Inc., Alexandria, Va.*

The LogEtronic K-5 Enlarger (K for color) offers three unique features: (1) automatic dodging, (2) end point exposure control, and (3) automatic color correction. The K-5 is designed to produce "the best print, the first time"—without test prints or errors due to "subject failure."

A variety of Ektacolor "first prints" made with the K-5 are compared with prints from the same negatives made by several custom finishers. Differences in equipment, procedure, production time, and materials will be described. Differences in quality will be self-evident.

A High-Speed Color Printer, *A. M. GUNDELFINGER, E. A. TAYLOR, and R. W. YANCEY, Technicolor Products, Inc., New York, N. Y.*

A high-speed printer for making color paper prints from color negatives was engineered and constructed by Technicolor Corporation. The capacity of the printer is approximately 5,000 prints per hour. It utilizes color negatives in roll form and 7-inch-wide color paper. The printer has been engineered to achieve stability and reliability. To accomplish this aim, such principles as (a) a null system of exposure control, (b) constant intensity of light source, and (c) constant duration of exposure have been employed. These principles have avoided, respectively, (a) effects arising from photocathode sensitivity variation, amplifier and electronic drift, and variation of printing light intensity, (b) print quality variations caused by color temperature changes, and (c) reciprocity law failure and electronic equipment required to overcome this failure.

The exposure control system is based on the principle of constant-integrated energy transmitted by the negative and incorporates the features of density and color subject-failure correction and undercorrection.

Subject-failure corrections are accomplished electropneumatically by means of binary combinations of small holes punched into one edge of the negative on a precoding machine and framing is accomplished electro-optically by means of a single hole punched into the opposite edge of the negative on the same precoder. Undercorrection is accomplished by photometric means.

Photographic Image-Density Isolation, *FRANK SCOTT, Goodyear Aircraft Corporation, Akron, Ohio.*

High-contrast photographic prints are made in both positive and negative form and at various exposure levels from a continuous-tone photographic record of a cathode-ray tube radar presentation. A high-contrast positive print and a high-contrast negative print, selected on the basis of exposure from the original continuous-tone record, are superimposed and printed in register onto a high-contrast material. The resulting image is only part of the original image, that part being equivalent to the selected density range of the original continuous-tone record. The resulting image, having a known relationship to the radar energy displayed on the cathode-ray tube, is extremely useful in studies of radar reflectivity, stability of radar targets, and various other aspects of radar reconnaissance photographic recordings.

Rapid Color Process for Composite Display, *LYNE S. TRIMBLE, Ramo-Wooldridge, Los Angeles, Calif.*

A survey of the recent progress made in rapid color-production methods has been conducted as the result of a requirement for the preparation of a composite color display for large-screen projection in a minimum time. A map background is to be presented upon which a number of highly saturated color symbols are to be clearly discernible and in addition a permanent record is to be prepared. A review of the advantages and limitations of known color systems and processes provides a background for the evaluation of new rapid methods with display potentialities. Consideration of time, quality, reliability, and anticipated availability resulted in the choice of multilayer color films. The time factor was minimized by the masking and exposing of symbol areas in the preparation of a composite color slide.

Tuesday Evening, October 27

Photographic Applications

A Demonstration of Color Perception with Abridged Color-Projection Systems, *C. S. McCAMY, National Bureau of Standards, Washington, D. C.*

The way primary colors combine to produce colored pictures, the effect of using less than three colors, and the effect of adaptation and memory on object color perception are demonstrated. The development of primary color systems is traced from earliest times to the advent of monopack three-color photography. Color constancy and the effects of colored illuminants are demonstrated and their implications in color photography are indicated.

Underwater, a New Frontier in Naval Photography, *LT. GLENN M. BREWER, USN, U. S. Naval Photographic Center, Anacostia, Washington, D. C.*

When a camera is carried beneath the surface of the sea the environmental changes present a challenge as well as a new technical frontier in photography. Camera design, optics, filters, and film emulsions are of primary concern. The basic problems of light losses resulting from surface reflections, surface loss, scattering, and absorption are unalterable and unpredictable physical factors. The spectral composition of the illumination changes with every foot in depth and is different in various bodies of water. Water clarity is a limiting factor and of course varies with different water types as well as with weather conditions.

These problems are presently being studied in actual photographic operations by the Underwater Photographic Team of the U. S. Naval Photographic Center, Washington, D. C., and this paper will present some of the findings.

Solar Eclipse Expedition, *H. VON KLÜBER, The Observatories, University of Cambridge, Cambridge, England.*

Crevasse Detection (Motion Picture), *U.S. ARMY SNOW, ICE AND PERMAFROST, RESEARCH ESTABLISHMENT, Corps of Engineers.*

Wednesday Morning, October 28

Speed and Exposure

Color Reproduction Theory for Subtractive Processes, *J. Q. UMBERGER, Photo Products Department, E. I. du Pont de Nemours and Co., Inc., Parlin, N. J.*

Methods are presented for identifying the primary controlled by a dye, thus aiding the application of tristimulus theory to subtractive color reproduction and dye mixing. These methods are related to earlier suggestions of Hardy, Wurzburg, and Wright and are shown to be essentially equivalent.

Two Psychophysical Methods for Evaluating the Quality of Projected Color Slides, *WILLIAM W. WOODBURY, Eastman Kodak Co., Rochester, N. Y.*

The exposure indexes of reversal color materials for use in miniature cameras are normally based on the results of judgments of the quality of projected slides which differ only in the camera exposure they have received. These slides are projected for judgment in either of two ways: in the order of increasing or decreasing exposure; or in a random order with respect to exposure. The results with these methods are identical but the ordered sequence presentation is preferred because of the simpler programing and data-handling processes.

Speed Rating of Reversible Color Material, *SPENCER R. ALBRO and IRA B. CURRENT, Ansco, Binghamton, N. Y.*

Although color photography has been practiced for many years, there is no acceptable method of rating the practical speed of the material on a laboratory basis. Manufacturers' ratings have been obtained empirically by making practical camera exposures, and modifying this by application of other factors. A subcommittee of the American Standards Association has been actively considering this problem for several years and is about ready to present a workable method for rating the photographic speed of reversible color films. As part of this program, the Ansco Standards Department has conducted some psychophysical tests designed to evaluate the subjective assessment of the speed of color reversal films. The data obtained have resulted in a simple sensitometric method of rating film speeds which is essentially based upon the exposure represented by the midpoint of a straight line connecting net densities of 0.20 and 2.00 on the characteristic curve.

Safety Factors in Camera Exposures, *C. N. NELSON, Eastman Kodak Co., Rochester, N. Y.*

Many photographers have adopted the practice of giving less camera exposure for black-and-white films than is indicated by exposure meters set in accordance with the ASA exposure index of the film and calibrated in accordance with the American Standard for exposure meters. This practice is successful because the "standard" exposure contains a substantial safety factor and the reduced exposure gives negatives that are better from the standpoint of print graininess, definition, and ease of printing. The actual size of the safety factor has (for many years) been assumed to be 2.5, but the validity of this assumption has been questioned. Some writers state that the safety factor is as high as 4. The present paper is an attempt to obtain a new estimate of the size of the safety factor.

Automatic Exposure Controls for Amateur Cameras, *ALLEN STIMSON, Eastman Kodak Co., Rochester, N. Y.*

There are four general classifications of exposure controllers which differ according to the participation required of the operator. Examples of each type are shown by color slides. Motion pictures are used to show the functioning of the internal parts of each of the American-made automatic cameras. The interrelations of the electric driving instruments, gears, couplings, diaphragm blades, and cell are explained in detail and illustrated.

The accuracy of automatic exposure controllers can be measured in at least three ways. Actual picture taking of scenes is the least accurate method. The most accurate method is the measurement of the exposure in the focal plane. Formulas for predetermining focal-plane illumination for Standard Exposure are derived. Pictures illustrating laboratory and factory equipment for calibrating automatic exposure-controlled cameras are shown.

Wednesday Afternoon, October 28

Image Structure

A Method of Measurement of Non-Linear Distortion Caused by Photographic Lenses, *KOJIRO KINOSHITA, HIDEHISA SATO, and SIZUO TATUOKA, Nippon Hoso Kyokai (Japan Broadcasting Corporation), Technical Research Laboratories, Tokyo, Japan.*

In the evaluation of photographic lenses it is necessary to investigate the uniformity of the spatial frequency response over the image space. Though the uniformity of field can be determined from the complete response data, it is more practical to measure the response at one particular spatial frequency somewhat below cut-off frequency.

The authors made a square-wave chart of about 3mm pitch and 2mm length. After photographing the chart, they measured the density of the image locally, using a microphotometer, and determined its contrast. They measured the phase shift of the lens by an interference method.

In this method, the photographic lenses are considered as filters introducing non-linear distortions of spatial frequency. In practice, aberrations can be classified as non-linear distortions.

The Effect of Film Thickness Variations on Coherent Light, *ARTHUR L. INGALLS, Willow Run Laboratories, University of Michigan, Ann Arbor, Mich.*

The introduction of commercial photographic film into the aperture of an optical system disturbs the coherence of the transmitted light, due to variations in thickness and refractive index of the film. Such variations in film can be made visible, as contour lines, by light interference between the front and back film surfaces. Photographs of the interference pattern can be measured and calculations of light-path variations made.

Measurements taken on a number of films showed only a few films acceptable by Rayleigh limit standards. Theoretically, more films would be acceptable when immersed in a liquid whose index of refraction nearly equals that of the film. A liquid gate suitable for such use has been developed by Eastman Kodak Co. A diagram is included to show how closely the indexes of the film and liquid must match for any particular film quality to affect coherence, due to thickness, by no more than one Rayleigh limit.

Though a special effort is necessary to provide satisfactory films, some improvement can be obtained by the use of a liquid gate.

A Method for Obtaining Limiting Film Resolution as a Function of Exposure and Contrast Ratio, *E. E. HENRY and M. E. HARRISON, Willow Run Laboratories, University of Michigan, Ann Arbor, Mich.*

Photographic film is the best material known for maximum information storage in the smallest amount of medium. Because data can be inserted in independent channels, the limiting channel spacing needs to be known so that the uniqueness of each is preserved.

This paper describes a method for determining the spacing which consists of contact-printing the image from a mirror-surfaced optically-flat glass block on a test film. In the mirror surface, lines, 50 microns wide, are engraved with a

variable spacing from 8.5 "TV" lines/mm to 62.5 "TV" lines/mm. The image thus printed is scanned with a specular densitometer and the light transmission recorded. The scanning aperture is 5 microns.

The ratio of contrast at any spatial frequency to that at a low frequency (8.5 lines/mm) can be determined. This procedure is carried out with different amounts of exposure, all film being developed under constant conditions. The relationship between light transmission through the image and the limiting resolution for a given contrast ratio, e.g. (0.707), is determined. Several examples which employ commercially available films are given.

About the Resolving Power of Photographic Materials, *H. THIRY, Université de Liège, Laboratoire de Physique Générale, Liège, Belgium.*

The photographic image of a sinusoidal interferential signal (Lloyd mirror) can be measured with accuracy, using the photographic image as a diffraction grating.

When observed in this way, photographic materials reveal a much higher limit of resolution than can be estimated by microscopic or microphotometric means of observation. Highly sensitive negative materials are able to resolve 300 lines/mm and ordinary positive materials 600 lines or more, even when ordinary light is used for the photography and measurement.

The Image Transmission Carrier in a Photographic System, *KOJIRO KINOSHITA, HIDEHISA SATO, and MINORU YOSHIMURA, Nippon Hoso Kyokai (Japan Broadcasting Corporation), Technical Research Laboratories, Tokyo, Japan.*

To examine the contribution of the granularity of film, the surface structure of photographic paper or the mesh-form of the halftone process to the printed image, they are treated as a carrier of the spatial frequency spectrum.

The significance of practical observations of information transfer in printing and the effect of "silk" surface photographic paper was confirmed.

The Effect of Image Motion on the Detail Rendition of Photographic Systems, *ROBERT N. WOLFE and SAM A. TUCCIO, Eastman Kodak Co., Rochester, N. Y.*

A theoretical discussion is given to show the way in which the various photographic parameters such as lens focal length, aperture diameter, emulsion sensitivity, scene luminance, and granularity can be varied so that, for a given amount of linear image motion, detail rendition can be optimized. The conclusions are confirmed by experiments.

Effect of Developer Composition on the Microstructure of Photographic Images, *J. H. ALTMAN and R. W. HENN, Eastman Kodak Co., Rochester, N. Y.*

A series of developers has been formulated in which the sulfite concentration and the Elon concentration have been systematically varied. The microstructural properties of the three current Kodak miniature camera films processed in these solutions have been examined.

The effects on image structure produced by the various developers were not the same for the three emulsion types. It was also noted that graininess and sharpness did not necessarily increase and decrease together. The combined variations of sharpness, graininess, and speed are considered in terms of the informational sensitivity concept of Zweig, Higgins, and MacAdam.

High Resolution Xerox by Aerosol Development, *J. T. BICKMORE, M. LEVY, and J. HALL, Haloid Xerox, Inc., Rochester, N. Y.*

Resolutions in excess of 100 line pairs per millimeter can be obtained by several different xerographic techniques. This paper covers studies on aerosol development of selenium photoconductors. Image resolution, density, and general quality were determined as functions of process parameters. The charged selenium plate was contact-exposed to a reduced parallel-line test chart. The xerographic plate was then developed by passing an aerosol containing fine charged developer particles between the xerographic plate and a closely spaced conductive electrode parallel to the xerographic plate. Important process parameters were found to include the relationship between developer powder charge and xerographic plate charge, development time, aerosol concentration, and the potential of the development electrode relative to the xerographic plate. The period between exposure of the charged photoconductor and development could be prolonged for 30 minutes or longer with no resolution loss. Resolution in the range from 140 to 200 lines per millimeter was readily obtained. There was no evidence to suggest that a fundamental resolution limit due to the structure of the selenium plate had been reached.

Wednesday Evening, October 28

Cocktail Party

Thursday Morning, October 29

Sensitization and Photo Theory

A Correlation of the Chemical Structures of Some Triazolopyrimidines with Their Photographic Effects, *VAUGHAN C. CHAMBERS, Photo Products Department, E. I. du Pont de Nemours and Co., Inc., Parlin, N. J.*

The effects of twelve triazolopyrimidines on the fog and speed stability of an experimental silver iodobromide emulsion have been determined. The photographic effects have been correlated with the chemical structures of these compounds. The behaviors have been interpreted by postulating the formation of resonance-stabilized silver salts adsorbed on the grain surfaces. The extent of desensitization by these compounds varied inversely with the solubility of the silver salts and was most pronounced at low-intensity exposures. Several mechanisms of the actions of these compounds are discussed.

Some Correlations Between Reciprocity Failure and Optical Sensitization Effects, *EIICHI MIZUKI,* Institute of Optics, University of Rochester, Rochester, N. Y.*

When a chemically sensitized emulsion is treated with a silver halide solvent before exposure, it has been shown that there is a great decrease in sensitivity at high-intensity exposure but no appreciable change at low intensity.

In the present paper, this work was extended by making a spectroscopic study over a wide range of exposure intensities. Kodak Spectroscopic plates suited to use in several spectral regions throughout the visible were studied. Before exposure, the plates were treated with a 1g/l solution of sodium thiosulfate, rinsed in water, dipped in alcohol, dried, and then exposed to light.

*Present address: Research Laboratory, Fuji Photo Film Co., Ltd., Minamiashigara-cho, Kanagawa, Japan.

Adsorption and Structure of Sensitizing Dyes, *E. KLEIN and F. MOLL, Agfa Research Laboratories, Agfa AG, Leverkusen, West Germany.*

The adsorption of 12 symmetrical cyanine dyes to silver halide in a 1.2% gelatin solution has been determined. The dyes differ in the type of heterocyclic nuclei, as well as in the number of combining methine groups.

It is indicated that a relation exists between the basicity of the dyes ($N^{III} \longrightarrow N^{IV}$, determined through light absorption) and the adsorption to silver bromide (determined through the maximum obtainable covering of the grain surface). In a comparison of the dyes with an equal number of methine groups, the adsorption increases with increasing basicity of the ring. In the same manner, the adsorption is intensified when, with an identical basic structure, the number of methine groups is increased.

Each adsorption isotherm passes over into a range of saturation, which in the case of intensively basic dyes corresponds to a monomolecular covering of the silver bromide (provided the adsorption takes place "edge on" to the grain). Dyes with more limited basicity show a covering of between 3 and 80% of the surface at disposal, which indicates the existence of ranges of different "activity" on the grain surface of the silver halide.

Experimental Studies on the Mode of Action of Sensitizing Impurities in Thin Crystals of Silver Bromide, *W. WEST and V. I. SAUNDERS, Eastman Kodak Co., Rochester, N. Y.*

In the development of the theory of photographic sensitivity, it is important to understand the behavior of impurities in silver bromide as traps for electrons and positive holes under conditions which closely match those of photographic practice. Thin, single crystals of silver bromide, up to 100μ thick, exhibit, after exposure to ultraviolet light, various image effects at sites remote from the zone near the surface of incidence, wherein all effective absorption occurs. The appearance of latent-image centers at such sites is attributed to diffusion of electrons from the absorption layer, and of bleaching effects on latent fog centers or of adsorbed dye, to diffusion of positive holes. The impurities affect the relative production of latent-image centers and of bleached centers according to their trapping of electrons and positive holes, respectively. The introduction of a layer of impurity in the interior of the sheet yields particularly illuminating results. A silver sulfide layer is found to trap both electrons and positive holes at low, as well as at high, exposure levels. The trapping properties of centers associated with the introduction of Cd^{++}, I^-, and chloroiridite ion will also be described.

Effect of Organic Stabilizers on a Photographic Emulsion, *THOMAS R. THOMPSON, Ansco, Binghamton, N. Y.*

Certain organic compounds commonly reported as photographic emulsion stabilizers reduce the rate of sensitization of a medium-speed silver-bromoiodide emulsion. When added at the beginning of the second digestion, 5-mercapto-1-phenyltetrazole had the greatest retarding action of those studied. Benzotriazole and 7-hydroxy-5-methyl-2,3,4-triazaindolizine were moderately active while 5-nitrobenzimidazole had little effect. Only 5-mercapto-1-phenyltetrazole caused a marked loss of speed when added to the fully sensitized emulsion prior to coating. Gelatin layers of yellow colloidal silver, print-out silver, and latent image silver particles were treated with the stabilizers. The effects of stabilizers on the silver particles which catalyze physical development of these model systems were studied. 5-mercapto-1-phenyltetrazole had a much greater inhibiting action than the other three compounds. The similarity between the retarding effects of the stabilizers in both the silver particle systems and the emulsion system suggests that the compounds are adsorbed to active centers or partially formed sensitivity specks and prevent their growth.

The Effect of Chemical Ripening on the Photographic Response to Light, X-, and Gamma-Radiation, *D. A. NEPELA and H. F. NITKA, Ansco, Binghamton, N. Y.*

The object of this investigation was to study the latent-image formation in a AgBr/I emulsion at various stages of chemical ripening when exposed to different radiation energies (high and low intensity light, x-, and gamma-radiation). Surface, internal, and conventional development were applied, in addition to physical development. The relationship of the photographic response under these conditions of exposure time, radiation energy, and development provides some valuable clues to the relative efficiency of latent-image formation.

Studies on Sensitization of Photographic Emulsions to X-Ray, *YASUO WAKABAYASHI, Konishiroku Photo Ind. Co., Ltd., Tokyo, Japan.*

It has already been reported that divalent lead ion coprecipitated with silver bromide increased the x-ray sensitivity of a photographic emulsion and decreased the degree of solarization. There was a close correlation between solarization by light and sensitization to x-ray. It was hypothesized that if the heightened x-ray sensitivity was a consequence of keeping positive holes from recombination with electrons, the solarization would likewise be decreased.

With this in mind, further studies have been made on the sensitization to x-ray by other metal salts such as thallous nitrate and thallous bromide, and on the solarization of the emulsions thus sensitized.

Thursday Afternoon, October 29
Sensitization and Photo Theory

A Mathematical Approach to Monobath Kinetics, *RICHARD E. SWING and SHEILA A. BARRY, Itek Corp., Boston, Mass.*

Despite the large accumulation of empirical knowledge, each new monobath must be formulated by trial and error. This suggests a definite need for an investigation of monobath kinetics which might reveal certain invariant characteristics and lead to a more thorough understanding of the basic process. If the kinetic behavior were known, the trial and error approach to monobaths might be replaced by a systematic method. A mathematical equation is presented which represents the kinetic behavior of monobaths. From this equation a relationship is derived which predicts an optimum reaction velocity, implying a critical balance between the competing development and fixing activities. Experiments designed and carried out by the authors substantiate the kinetic relationships.

Comparison of Development Kinetics of a Color Developer and a Black-and-White Developer, *R. B. PONTIUS, R. M. COLE, and R. J. NEWMILLER, Eastman Kodak Co., Rochester, N. Y.*

The kinetics and activation energies for development of image and fog silver in a positive-type emulsion by a substituted *p*-phenylenediamine type of color developer and by a Metol-hydroquinone developer have been compared to determine the features which contribute to the superior discrimination between image and fog by the black-and-white developer. Although the kinetics of image development are identical in the two cases, the developers differing only in the rate constants, the kinetics of fog development are different. The difference in fog kinetics is thought to be related to evidence that fog consists of a chemically developed component and a physically developed component.

The Influences of Some Addition Agents on the Color of Developed Silver from Liquid Photographic Emulsion, *KIYOSHI FUTAKI, YASUSHI OH-YAMA, and TOH-ICHI IWASAKI, Mitsubishi Paper Mills Co., Ltd., Kyoto, Japan.*

The influence of some addition agents on the color of developed silver image was investigated. A photographic silver chloride emulsion was developed in the liquid state by a dilute Phenidone-hydroquinone developer after adding small amounts of several organic substances. Development was stopped and the emulsion was fixed by adding a small portion of a stop solution and a fixer in succession. Finally, the spectrophotometric density of the silver dispersion was measured.

Among the substances tested were alkyl homologues of 6-alkyl-7-hydroxy-5-methyl-1,3,4-triazaindolizine(I), 2-alkyl-1,3,4-oxadiazoline-5-thione(II) and 2-alkyl-5-amino-1,3,4-oxadiazole(III). The color became more blue-black with an increasing number of carbon atoms in the alkyl groups in

I, but with a decreasing number in the homologues of II. In the case of III the maximum effect in blue-black tone was observed with nine carbon atoms.

Melting Point of Gelatin Gel Containing Chrome Alum as a Hardening Reagent, *MIKIO TAMURA, MICHIO KURATA, and KANJI FUJITA, Department of Industrial Chemistry, Kyoto University, Kyoto, Japan.*

The melting point of gelatin gels containing chrome alum was measured under various conditions of gelatin concentration, chrome alum content, and reaction time. The hysteretic effect in the system after addition of chrome alum was also investigated.

A marked elevation of the melting point was observed for gels cooled soon after the chrome alum addition. However, gels cooled some time after the chrome alum addition had lower melting points than gels to which no chrome alum had been added. This shows that the chromium links formed in the gel state can promote the hardening effect, but the chromium links formed in the sol state counteract the hardening effect.

It is inferred that, in the gel state, the chromium links are formed in the amorphous region of the gel structure and, therefore, make the gelatin micelles more stable to heating, while the chromium links formed in the sol state hinder the development of gelatin micelles.

Photothermographic Sensitization of Mercurous Oxalate by Mercurous and Silver Iodides, *PAUL B. GILMAN, JR., PHILIP A. VAUGHAN, and P. A. VAN DER MEULEN, Rutgers, The State University, New Brunswick, N. J.*

Gelatin emulsions containing mercurous oxalate and mercurous iodide have photothermographic sensitivity to visible light. Sensitometric studies show that the sensitization of mercurous oxalate by mercurous iodide is increased considerably by the addition of silver iodide. X-ray diffraction studies and photomicrographs of the solid-state reactions involved indicate that the sensitization of mercurous oxalate is caused by the photolysis of mercurous iodide to form mercury and mercuric iodide.

In the absence of silver iodide, yellow mercuric iodide is a product of photolysis. If silver iodide is present, it acts as an acceptor for the photolytically produced mercuric iodide to form the complex, Ag_2HgI_4, so that the efficiency of the photolysis of mercurous iodide is increased.

Enhancement of Photographic Speed and Sensitivity by Electric Fields, *JEROME ROTHSTEIN, Edgerton, Germeshausen and Grier, Inc., Boston, Mass.*

Experiments were performed to test the hypothesis that strong electric fields applied to an emulsion during light exposure might increase speed or sensitivity. Kodalith Ortho Stripping Film emulsion was mounted on a transparent electrode (tin oxide coated glass) and dried. Exposures were made in an E.G.& G. Mark VI Sensitometer, with voltage across the electrodes synchronized with a flash lasting 10^{-4} seconds. A dramatic increase in both contrast and darkening occurred at higher intensities. The extrapolated trend at low intensity suggests real increase in speed, not just increased gamma.

Thursday Evening, October 29

Banquet

Friday Morning, October 30

Processing

The Quality of Water for Photographic Processing, *LLOYD E. WEST, Eastman Kodak Co., Rochester, N. Y.*

There are no standards for the purity of water required for processing photographic materials. This paper describes the photographic effects of impurities sometimes found in water. The effects of water hardness, suspended matter, chlorine, chloride, algae, slimes, pH, copper, iron, manganese, lead, fluoride, zinc, tin, total salt content, and sulfide are described.

Photographic Developing Agents: 2. Quinones, *R. W. HENN, J. F. TINKER, and H. L. FIELDING, Eastman Kodak Co., Rochester, N. Y.*

Quinones form strong developers in alkaline solution in the absence of sulfite. The activity is probably due to a hydroquinone or a hydroxyhydroquinone, formed by the addition of the hydroxide ion. The developer is less active in the presence of sulfite, where the active product is probably the hydroquinone sulfonate. Polyhydroxyanthraquinones are shown to develop, but less actively than corresponding benzene and naphthalene derivatives.

Silver Sulfide in the Photographic Image, *CHESTER I. POPE, National Bureau of Standards, Washington, D. C.*

If fixation has taken place in a thiosulfate fixing bath, a silver sulfide residue is always left in the gelatin layer when a photographic image is bleached. A definite amount of the silver in the image is sulfided during fixation, the amount depending on the type of light-sensitive layer. During bleaching, residual thiosulfate reacts with silver in the bleach bath to form silver sulfide. For one paper, it was shown that the amount of silver sulfide formed in the bleach bath increased with the increase in the concentration of the residual thiosulfate in the paper. The use of hypo eliminators was studied and a test procedure was evolved for testing the effectiveness of hypo eliminators. A procedure was developed for reducing the silver sulfide in an emulsion layer to silver so that the silver sulfide can be determined in terms of the optical density of the silver deposit.

The Stability of Concentrated Ammonium Thiosulphate Solutions at High Temperature, *G. I. P. LEVENSON, Kodak Ltd., Harrow, Middlesex, England.*

Concentrated liquid fixers and solutions of thiosulfate-sulfite mixtures were incubated in sealed glass tubes at 60°C. The effect of pH, sulfite concentration, dilution, etc., on the period of stability of the solution before the sharp onset of sulfurization was observed. The solutions were analysed where necessary. The stability of the thiosulfate solutions was not primarily dependent on whether sodium or ammonium salts were used, but it rapidly decreased as the pH and sulfite concentration were lowered. The sulfite reacted with the thiosulfate. When all the sulfite was consumed, the thiosulfate decomposed.

Variable Negative-Image Development in Reversal Color Processing, *PAUL B. MEANS and V. MICELI, Ansco, Binghamton, N. Y.*

The first development step of reversal films, particularly reversal color films, involves two basic reactions: (1) the formation of a negative silver image and (2) a dissolving action on the residual silver-halide grains. Although these reactions are interrelated to a considerable degree, under some conditions they may be separated. Studies using the "split" development technique are useful in the design of photographic materials.

The "split" technique also offers an opportunity to adjust the practical emulsion speed after normal first development reaction is completed and the film has been short-stopped, hardened, and re-exposed.

Suitable solvent baths are described and some results obtained by this technique are demonstrated.

An Edge Effect in Color Films Caused by Distortion of the Developed Image When a Hardening Bleach Is Used, *HOBSON J. BELLO, JR., and DAAN M. ZWICK, Eastman Kodak Co., Rochester, N. Y.*

An edge-effect phenomenon occurring in color films is shown to be a distortion of the developed image, resulting from differential hardening of gelatin in image and non-image

areas during bleaching. The subsequent dislocation occurs during drying. The variables involved in this effect are described. This phenomenon is illustrated for Eastman Color Intermediate Film, Type 5253.

The Interrupted Processing Method of Compensation for Exposure Errors in Aerial Photography, *N. A. EXLEY and C. E. IVES, Eastman Kodak Co., Rochester, N. Y.*

A method of compensating for overexposure errors in aerial photography involves the use of "interrupted" processing. The film is first developed to low photographic speed in a "primary" developer, inspected to determine the amount of image produced by this treatment, and then given supplementary "secondary" development to obtain the required increase in speed. Procedures are given in which (1) the film is dried following primary development, permitting the use of conventional processing equipment, or (2) the film is examined or scanned continuously in the wet state after primary development, usually on a specially designed processor.

Friday Afternoon, October 30

Processing and Apparatus

Recent Improvements of Stabilization Processing, *ROLF S. BRUENNER, U. S. Army Signal Research and Development Laboratory, Ft. Monmouth, N. J.*

Restrictions placed upon thiourea stabilizing processing are: (1) formation of intense fog if alkaline developer becomes contaminated with thiourea, (2) fading of stabilized prints on ordinary paper base at high humidity, and (3) stickiness of the gelatin layer caused by thiourea processing at elevated temperatures.

Approaches to overcoming such restrictions included stabilization of the silver-thiourea complex, use of thiourea derivatives, protection of the silver image by additives, and prevention of excessive swelling of the gelatin by use of hardening agents, thiourea derivatives, and high concentration of stabilizer.

A probable fading mechanism is proposed. A possible intermediate in the fading reaction may be useful as a bleach bath component.

A Versatile, Fine-Grain Glycin-Phenidone Formula for Simultaneous Development and Fixation of Photographic Films, *SIMEON BRAUNSTEIN, Avco-Everett Research Laboratory, Everett, Mass.*

There is an increasing interest in simultaneous photographic development and fixation, since the monobath results in considerable simplification of processing procedures and equipment as well as reduction in weight and space. This is highly desirable, especially in field and aircraft applications.

An improved developer-fixer monobath using glycin and Phenidone as developing agents has been devised. Addition of a small amount of soluble iodide increased the emulsion speed of such slow- and medium-speed films as Adox KB-14, Kodak Panatomic-X, Plus-X, and Super-XX. Other films successfully processed include Kodak Micro-File, Kodalith Ortho, and dental x-ray films.

The monobath produces fine-grain negatives of good gradation and acutance, and low fog level. It has been used successfully, with no change in formula, for several types of emulsions, and at temperatures up to 85°F in field operations. Shelf and working life are good, since glycin does not oxidize readily in the presence of air.

Commercial Photographic Monobaths, *HARRY S. KEELAN, Cormac Chemical Corp., New York, N. Y.*

A discussion is given of the chemistry of monobath processing, the problems involved in its transition from a scientific curiosity into a commercial reality, and a description of its uses and potential applications.

Sensitometric curves are given for the most popular films and papers, processed by Unibaths.

Automatic Processing of Photographic Code Plates for Electronic Telephone Switching Systems, *D. C. KOEHLER, Bell Telephone Laboratories, Inc., Whippany, N. J.*

Electronic telephone-switching systems now being developed require large-scale memories with high-speed random access. This memory is provided by the Flying-Spot Store which stores information in binary code in the form of tiny clear and opaque areas on photographic plates. The information on these plates controls the operation of the office and keeps track of the correlation between telephone directory numbers and the location of the line terminals in the telephone office to which these numbers have been assigned.

Periodic changes in the stored information require preparation of new plates. After exposure in the Flying-Spot Store, the plates are subjected to a 15-step reversal process in the Automatic Plate Processor. The Processor handles one or two plates at a time and is highly reliable, even when used by personnel with little or no photographic training.

Cut-Sheet Graphic Arts Film Processor, *GLEN C. BULL, Haloid Xerox, Inc., Creve Coeur, Missouri.*

The Haloid Xerox Lithoflo Processor provides accurate control of absolute time, temperature, and agitation especially for use in graphic arts sheet film processing. Films are transported without the use of hangers or clips. The processing capacity of the developer exceeds that obtained with tray development. Processing of films of various support thickness and the high quality of development are described, as well as the design and construction of this processor.

A Review of Recent Developments in Automatic Processing, *OSCAR FISHER, Oscar Fisher Co., Inc., Newburgh, N. Y.*

A review is given of the characteristics of recently designed equipment for processing sheet film, roll film, sheet paper, and roll paper. Various systems of transport and agitation are discussed and the relation between chemical systems and machine design is considered. An appraisal is made of automatic processing in comparison with manual. It is concluded that the silver halide systems in an era of automation require the best application of theoretical and practical knowledge in order to render their best service and compete successfully with other systems.

Storage Envelopes for Photographic Negatives, *R. W. HENN and I. A. OLIVARES, Eastman Kodak Co., Rochester, N. Y.*

Fungus growth on negatives can be prevented or greatly reduced by enclosing them in envelopes impregnated with a suitable fungicide. When more than one negative is enclosed, additional protection can be obtained by interleaving with similarly treated paper.

The most successful of the fungicides tested is sodium pentachlorophenate. Envelopes made from paper impregnated with this fungicide protected negatives against fungus growth for periods of up to eight years under moist, tropical conditions. Stability is improved by the use of non-aqueous adhesives, edge-seams, and flaps to close the envelopes. Specific recommendations for storage envelopes and interleaves are made.

This Advance Program has been prepared by the Papers Committee.

The Society of Photographic Scientists and Engineers

Box 1609 • Main Post Office • Washington, D.C.

OFFICERS

President	GEORGE T. EATON, Building 59, Kodak Park, Rochester 4, New York
Executive Vice President	STEVEN LEVINOS, Ansco, Binghamton, New York
Engineering Vice President	JOHN A. MAURER, 116–118 West 29th Street, New York 1, New York
Editorial Vice President	R. CLARK JONES, Polaroid Corporation, 730 Main Street, Cambridge 39, Mass.
Financial Vice President	HERBERT MEYER, 325 Sequoia Drive, Pasadena 2, California
Secretary-Treasurer	C. GRAHAM EDDY, 110 Kennedy Street, Alexandria, Virginia
Managing Secretary	EDWARD S. COBB, Box 1609, Main Post Office, Washington, D.C.

CHAPTERS *and* CHAPTER OFFICERS

Binghamton, New York	*President*	HEINZ F. NITKA, Ansco Research Laboratoy, Binghamton, New York
	Secretary	E. SCUDDER MACKEY, Stone Road, MR-98, Binghamton, New York
Boston, Massachusetts	*President*	WILLIAM M. DRUMM 116 Forest Street, Needham, Massachusetts
	Secretary	ARTHUR J. ROSENBAUM, 44 Gleason Street, Framingham, Massachusetts
Chicago, Illinois	*President*	DAVE KAZEN, 8526 Osceola, Niles, Illinois
	Secretary	PHILIP J. LETOURNEAUX, 4 Wilson Court, Park Forest, Illinois
Cleveland, Ohio	*President*	R. E. BIRR, c/o General Electric Lamp Division, Nela Park No. 281, Cleveland 12, Ohio
	Secretary	CLINTON K. HAMLINK, 2230 South Overlook Road, Cleveland 6, Ohio
Ithaca, New York	*President*	B. L. HERRINGTON, 316 Eastwood Avenue, Ithaca, New York
	Secretary	DAVID O. FLETCHER, 1314 East State Street, Ithaca, New York
Monmouth, New Jersey	*President*	JOSEPH MANGIARACINA, 30 Brook Avenue, Little Silver, New Jersey
	Secretary	MISS MARILYN LEVY, 100 McLaren Street, Red Bank, New Jersey
New York, New York	*President*	FRANK G. BACK, 55 Sea Cliff Avenue, Glen Cove, New York
	Secretary	LT. HAYDEN B. PEAKE, Army Pictorial Center, 35-11 35th Avenue, Long Island City 1, New York
Rochester, New York	*President*	JAMES C. GRIFFIN, Haloid Xerox Inc., 282 Hollenbeck Street, Rochester, New York
	Secretary	W. F. WALKER, Research Laboratories, Eastman Kodak Company, Rochester 4, New York
Southern California	*President*	CLAYTON S. CHAPEN, 652 Calle Miramar, Redondo Beach, California
	Secretary	ROBERT J. KEIDATZ, 7519 Baird Avenue, Reseda, California
Washington, D.C.	*President*	KENNETH B. LUDWIG, 1054 31st Street, N.W., Washington 7, D.C.
	Secretary	LOUIS WERNER, 3610 North Powhatan Street, Arlington 13, Virginia

Sustaining Members / Society of Photographic Scientists and Engineers

Abrams Instrument Corporation

Aero Service Corporation

Ansco Division, General Aniline & Film Corporation

Atkinson Laboratory, Incorporated

Bar-Ray Products, Incorporated

Bausch & Lomb Optical Company

Bell & Howell Company

Charles Beseler Company

Burke & James, Incorporated

Byron Motion Pictures, Incorporated

Chemco Photoproducts Company, Incorporated

Chicago Aerial Industries, Incorporated

Consolidated Film Industries

E. I. du Pont de Nemours & Company

Eastman Kodak Company

Edgerton, Germeshausen & Grier, Incorporated

The EdnaLite Optical Company, Incorporated

Elgeet Optical Company, Incorporated

Fairchild Camera & Instrument Corporation

Farrand Optical Company, Incorporated

Oscar Fisher Company, Incorporated

The F-R Corporation

General Electric Company

General Film Laboratories Corporation

Graflex, Incorporated

Grant Photo Products, Incorporated

W. & L. E. Gurley Company

Haloid Xerox Incorporated

Hardale Associates

Hi-Speed Equipment, Incorporated

Houston Fearless Corporation

Charles A. Hulcher Company, Incorporated

Philip A. Hunt Company

Hycon Manufacturing Company

The Kalart Company, Incorporated

Kollmorgen Optical Corporation

LogEtronics Incorporated

L-W Photo Products Company

J. A. Maurer, Incorporated

The Morse Instrument Company

National Research and Chemical Company

North American Aviation, Incorporated

Pako Corporation

Photogrammetry, Incorporated

Polaroid Corporation

Rolor Industrial Corporation

Simmon Brothers, Incorporated

Technicolor New York Corporation

Tiffen Marketing Company

Viewlex, Incorporated

Wollensak Optical Company

Zoomar, Incorporated